NAVIGATOR- A NAVIGATION SYSTEM FOR THE VISUALLY IMPAIRED

BY

MEGHA AILAVAJHALA

THESIS

Submitted in partial fulfillment of the requirements
for the degree of Master of Science in Computer Science
in the Graduate College of the
University of Illinois at Urbana-Champaign, 2015

Urbana, Illinois

Adviser:

Professor Wai-Tat Fu

ABSTRACT

This paper proposes a navigation system on an android platform, Navigator, designed for the visually impaired for easy and independent travel. People with physical disabilities have a tough time going from one place to another and the conventional methods are using canes or guide dogs or human assistance. This system would use voice-to-text and text-to-speech technologies to communicate with the user easily effectively. The system would also give turn-by-turn voice navigation while detecting any obstacles on the way.

Two user studies were conducted to better understand these characteristics and features of the system. Visually impaired people who were familiar with navigation systems as an application on their mobile devices were selected to use Navigator and give us their feedback based on the ease of use, speech to test functionality etc. In the first user study, the participants were asked to use the app while walking in a pre-determined path with obstacles. This would give them a real life situation to work with and it was found that most of the participants were comfortable with the object detection technology. However, they wanted it to be a bit more precise and give more feedback in terms of the recognition of the object. They were also asked to use the speech synthesizer technology to understand the routes and instructions being told. Most of the participants were able to clearly understand them but they wished for a more detailed instruction

The results from the first user study led us to conduct another study. This time our main focus was to compare Navigator with other existing apps like Google maps. This comparison would help the participants and us, get a better idea of how different or similar both the apps were. On specific routes, the participants were asked to use Google maps and Navigator alternatively. Some of the differences in both the navigation systems were the distance being calculated- Google maps used miles while Navigator used blocks, repetition of the last instruction being available, etc. The results were quite interesting. We noticed that as the users used the system, with time they would make fewer errors, in terms of incorrectly clicking any button or not understanding any instruction. For most of the participants the routes chosen was not familiar so it was quite interesting to see how dependent they were on either of the Navigation system but were able to flow Navigator better as the distance was in blocks, which they were quite used to.

From both the user studies, we have tried to improve the functionalities of the system so that we can give the users a better user experience. One change that was done included the map in the Navigator being reduced in size in the second study, to give space to bigger buttons. After the second user study, we decided to include the functionality of the system giving the instruction automatically as one approaches a turn instead of having a button to click on. The results have proven that the participants appreciate the Navigator system more as the functionalities are more applicable and supportive of the needs of the visually impaired.

Author Keywords

Visually impaired; Navigation; Map; Android; Voice Navigation; Object detection, Google Maps, Navigator, button size, blindness level, Google API, directions, turn-by-turn instruction, speech synthesizer, camera

ACKNOWLEDGMENTS

I wish to express my deepest appreciation to Professor Wai-Tat Fu for all his help and support. I am tremendously fortunate to have him as my advisor and thank him for supporting this project and giving me thoughtful feedback always aimed at helping me move forward.

I would also like to thank the computer science department for giving me the opportunity to hone my teaching skills. Being an assistant helped me become more confident and erudite in my area of research, and in turn become a better mentor to the students.

Besides my professors, I would also like to thank my friend, Neha who has been with me through all my highs and lows; Himay, Dharthi and Aditya who have taught me to never give up; all my friends back in India- Shikha, Dheeraj, Dev, Rauni, Sameer, Nitish and Jyotsna who have had immense faith in me and pushed me to do my best.

My acknowledgment would not be complete without thanking my parents, my sister and my entire family who have supported me throughout my life. I would like to express my sincerest gratitude to my cousin Sarat, who helped raise my morale in the toughest times.

Table of Contents

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

Navigation systems have been around for centuries now. Right from using paper maps to radio navigation, devices have been used for travelling from one place to another. In the early days, the device would be on board of the vehicle or be located someplace else and could be connected using radio signals. However, with the increase in technology, these systems have become portable and are small enough to fit on the palm of humans.

Navigation not only implies for people to travel from one place to another, but also helps in a giving a spatial representation of the environment. The process of humans analyzing the environment and representing it in a mental and graphic manner is known as the spatial updating. It is a cognitive process that updates and computes the spatial environments as the individual moves; based on the perceptual information it receives. It is very important for the navigation systems to have the ability to work on the same concept.

There has been a lot of work in developing technology for improving the lives of the visually impaired. Be it inventing new and improved Bluetooth canes or improving the voice system in the hand held devices. People are trying every day to improve the technology to help make them independent. Easy hand held devices can help them with the navigation. The person would however have to carry an extra device with him besides a guide dog or a cane. It is important to not only develop technology to improve the technical aspect of daily activities, but to also simply and ease the discomfort of carrying several devices.

The main functions of any navigation system include determining the location of the vehicle, suggest directions from one location to another, and provide information about the buildings and obstacles and also information about the traffic conditions and alternative routes. With the advancement in technology, these days one can also get directions based on the mode of transport- bicycle, public transport, and private transport and on foot.

A navigation system in general should also be educated enough to make guesstimates on the route one can take. Also, it should able to defer to the new route in case someone gets lost. It is also important to have a well-established and working speech synthesizer system. These days many people are multi-tasking and no one has the time to sit and g through the app by clicking buttons. Most of the functionalities are dependent on voice commands and any navigation system should be updated with the technologies. It would also be essential for the system to be practical as well as fast. It would not make sense for it to update at a much slower speed than the user.

Many people use navigation system in their portable devices like Google maps and Apple maps. These systems have both voice navigation and include turn-by-turn navigation system. Although they seem to be simple features these systems are not practical for people with physical disabilities, particularly users with visual impairment. A visually impaired person would access a mobile phone in a drastically different manner than one who is not visually impaired. It is very important to design and develop a system that can accommodate all the essential features and more for the said group of people.

A few characteristics to be included in a navigation system for the visually impaired include them having informed instructions. A more detailed information given as a response to the users would enable them to understand the route being taken. Not only should the system be able to tell them the route to take but helping them give various streets they are crossing or information about their surrounding would also make be helpful for them in the future.

The talk back options is now available in almost all phones so that people with visual impairment can easily use the device which would otherwise be difficult because of the absence of any physical buttons on the current technology of smart phones. Also, it is important for them to have a system that can help them give an option to repeat an instruction in case it wasn’t clear or loud enough the first time.

It is quite common for the visually impaired to bump into different objects in their path due to lack of vision. The biggest problem being faced by this group of people is the fact that they are not confident to walk in busy or unfamiliar streets, as they don’t know what to expect in their way. Having a navigation system that cannot only help them navigate but also detect and help them avoid obstacles would mean one thing less to worry about.

Another important aspect involved in a navigation system is known as the spatial updating. Spatial updating is a continuous and automatic process where an internal map is created that updates the objects seen in the environment. For people who are visually impaired, more information is always better. Not only would one like to know of the current location but would also like to know the various objects in the environment. Traditional navigation techniques do not help in detecting any obstacles, which is a big problem.

Having a single application that not only help with the navigation but also detect obstacles would solve the purpose. The users would have to carry just one device besides their guide dog or canes, in this case a phone. It is quite possible that a user can hang the device from the neck such that he has one hand free and does not have to hold all the devices. This would not only relieve the users from managing numerous objects, but they can focus on other things too.

There has been an exponential increase in the number of android phone users in the recent years because of its customizable qualities and cheaper devices. Since android platform is available open source, there has also been a drastic increase in the number of applications that can be added in the phone. Open source platform is not only free but also easy to use and design and thus, is quite popular. Some of the applications can be used to take pictures and analyze it in real time while others may involve direct feedback on a particular object using crowd sourcing. There are many applications that are used for navigation which give turn-by turn information of the route taken such as Google maps and apple maps.

As discussed there are many apps like Google maps or Blind Square that can be used for navigation and other apps like Tap Tap see and Cam find can be used to detect and analyze any objects. But there is no combination of both available. Instead of opening and toggling between two apps, it would be beneficial for a user to have navigation and obstacles detection in the same app. The question arises as to what features such an app should have to help the visually impaired people. Though we have discussed some basic characteristics that a navigation system must have, we are still unsure of the extent of those features, which would truly be useful for the visually impaired. Also, it is very important to understand how different spatial updating is for this group. Since spatial updating mostly depends on revising the environment that can be seen, it would surly work in a different manner for the visually impaired people.

This gives rise to the important question of whether such a mobile app can be developed. We decided to design and develop a system that can try to solve, if not completely fix the problem that visually impaired face during navigation. It was also important to constantly get feedback from them to understand and analyze their requirements better. The main goals of this thesis are:

1. Understanding the problems that the visually impaired face during their day to day travels, by conducting various user studies and asking them to complete the questionnaires.
2. Design and developing an android application (prototype) based on the feedback from the user study.
3. Conducting another user study to further improve the characteristics of the system and receive further feedback.

4. Continue various tests and find conclusive and conducive results to help the community.

CHAPTER 2

RELATED WORK

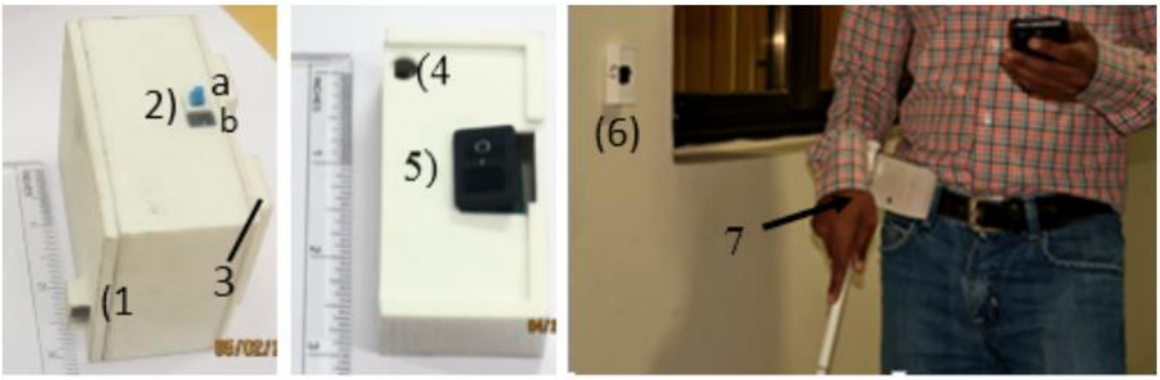
There has been a lot of work going in this field of assistance for the visually impaired. There are a lot of devices that have been designed for their benefit, such as Drishti, a wireless pedestrian navigation system [1], Path guided indoor navigation system [2] and others. The main problem with these systems is that they are external devices and expensive to use. People need to hold this equipment separately, which can be quite cumbersome to carry as they might already have a blind cane or a guide dog with them.

The Drishti [1] is a wireless system that uses numerous technologies like voice recognition and synthesis, wireless networks, Geographic Information System and Global Positioning system. It uses contextual information and customizes the routes based on the user's preferences. It constantly helps indicate the user the current location and gives it navigation based on current and dynamic data. Some particular objects in the environments are marked as landmarks to add more detailing to the environment. It is important for the people using this system to get information through auditory cues. This was based on the Dr. Theral Moore's input and reviewing literature on user requirements for blind. This literature helped me use the same cues in the system developed by us.

Fig 2.1: Dhrishthi maps

The system of Drishti was designed to be extra equipment that the users could wear long with the GPS receiver and a compass in the backpack. A head mount is available that has a headset integrated for the speech to text and vice versa system. Though the system works on simple dialogue exchange between the user and the interface, the biggest problem is the fact that there is an excess weight that one has to carry besides a guide dog, cane or a wheelchair. Also, the system loses signals near tall building and under tree canopies, which is a big problem as that proves this system, cannot be used on a more global basis. Another interesting point that proves it could not be used globally was that this system did not take into consideration the different distance metrics. The navigation was not given using a standard unit of measure, e.g.; in meters or blocks. This was a problem that I had anticipated when I was working on Navigator and decided to solve.

Path- Guided Indoor Navigation for the visually impaired [2] discusses a system that can be used in an indoor environment after downloading the floor plans of the said sections. There are audio instructions to help the visually impaired navigate from one place to another. The instructions include the distance required to travel, obstacles warning and position correction. This gave me the idea of adding the characteristics of obstacle detection to the new app so that one can use it in the outdoor environment too. This particular feature is especially important, as there are more mobile and dynamic objects in the outdoor environment.



(A)User Module (B) Wall module (C) User with our system

System prototypes. (1)IR receiver, (2a)tactile push button switch for operation, (2b)charging port and (3)belt fix, (4)IR transmitter and (5)switch, (7)user module, (6)wall module retrofitted in the building.

Fig 2.2: Path guide indoor navigation

Another interesting feature discussed in the paper that inspired me was the use of wireless technologies and computer vision. As the user walks, the application keeps receiving the current position and dynamically calculates the shortest path to the destination. The navigational directions are given to the user based on the waypoints and the turns taken by hm. Using computer vision, the system can recognize any obstacle using the IR receivers and having instructions to avoid them. With the help of a database of the landmarks available in the building, the system can detect the objects in the path of the user. The system also uses infrared sensors in each turn to mark the user's position accordingly and give the next step of instruction. The idea of giving instruction at each turn by keeping in mind the position of the user is very important and has been kept in mind considerably.

The system needs a lot of external help such as IR sensors in the building and could be used only inside a building, given that the floor plans are known to it. The fact that external permissions are required to download maps can be quite frustrating for a person and it was kept in mind while designing the application discussed in the paper. It was also important to keep in mind the turn-by-turn instructions given by the system and how often it was given. The analysis of the system also helped give some very interesting measures to analyze a navigation system in, such as, number of help seeking events, comparison of major deviation from the actual path, etc.

The graphical user interface for the modern system has been improving intensely and using a user-centered design, the interface has improved for the visually impaired too. It is important for any interface to be not only user friendly and easy to use but also have the required functional requirements and an easy design. These requirements were discussed in the Basic Human Computer Interface for the Blind [4] and with the help of this paper we can clearly understand the

There has been new application created for the visually impaired on the mobile devices so that they have one less thing to worry. These apps are not only cheap but also easy to use as the users are accustomed to mobile devices. The interface is also user friendly and has a lot of haptic characteristics for ease of use. Some research includes and indoor navigation system for the blind [3], for mobile devices. However, most of these apps are available only on iPhones. Most of the people all around the world carry android phones and there are not enough effective apps yet on them. There are also a lot of bugs that slow down the processing of the app due to which there is little or no help.

The application to be created is designed to work on mobile devices. So it is important to include all the features that make it easy to use. Navigational patterns and usable overview and zoom able features are some of the characteristics that all mobile applications are required to have. The Navigational Patterns and Usability of Overview + Detail and Zoom able User interfaces for Maps [5] gives us an idea of how the overview and details affects the usability, the different navigational patterns and how they are influenced by the different organizations of information spaces.

The paper also describes the various characteristics of the zoom able interface like geometric zooming, semantic zooming and common zooming and how the user needs to interact with the information space through spanning and zooming. According to the paper, having combined zoom and pan button was something most people describe as being not useful. This would mean that the users would like the zooming and panning abilities of an application to be kept separate.

The papers by Anke Brock, Philippe Truillet, Bernard Oriola, Christophe Jouffrais (Usage of Multimodal Maps for Blind People: Why and How [7]) and Shaun K. Kane, Meredith Ringel Morris, Jacob O. Wobbrock (Touchplates: Low-Cost Tactile Overlays for Visually Impaired Touch Screen Users [8]) talk about using touch screen and modal maps instead of a digital device. Having a paper or modal map would be much suitable as a person can use his sense of feel to understand the map. Both papers target specific problems that visually impaired participants face to identify, navigate and cross familiar and unfamiliar intersections. The ideas used in these papers helped me realize that it is important to take into consideration intersection and the user interaction. Open Street Map is an application prototype that the paper discusses in which importance is given to user interaction and has supporting information for each crossing and intersection. With this experiment in mind I could gather information on the intersections and crossing for the paths I had chosen for my experiment.

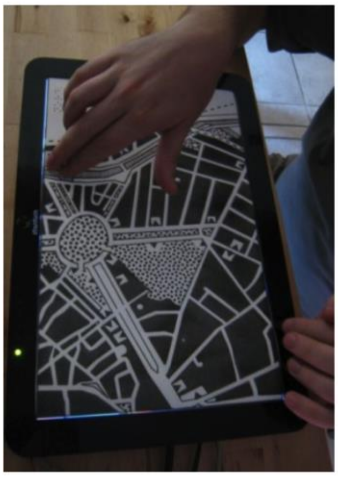


Fig 2.3: Multimodal maps

So far we have learned the following from our pre-study surveys and prior work research:

There are devices that can help then navigate from one place to another by giving them turn-by-turn instructions. However, these devices are either expensive or heavy and need to be bought separately besides their current helping device. Also, they are paper maps available that can help them use their sense of touch to understand the routes being taken and plan the trip accordingly. This would create a problem too as it would require them to be fully prepared before they start their navigation or they would be aware of only a small part of the area at a time.

When it comes to mobile devices, there are few applications that actually are easier to use by the visually impaired group. Using voice commands, one can find out their current location and also some important landmarks in their vicinity. Other aspect of the research work included them trying to identify the objects in front of them or in their environment by clicking pictures.

The biggest implication of the research done was that all these different system to help ease the problems of the visually impaired group were in separate devices. Our idea was to amalgamate all these features into one single app so that the users did not have to spend a lot of money in buying them individually. Another characteristic that I feel has not been added in the previous work is the inclusion of map and buttons in the same app. There are apps that have either of the features but not both. This is an important detail as it can be designed for completely visually impaired or partially visually impaired people. Taking the entire group into consideration can help us gain a better perspective in their needs.

Another component that I feel has not been taken care of are the unit of measure for the distance and the instruction given while navigating. Even though there are systems that give information about the next instruction, they do not use a standard measure. It is important to customize this to the audience we are targeting, for e.g.: in blocks which most people are comfortable using in the western countries. We should also be careful about how to word the instruction to make sure people whose native language is not English understand it too.

With these points, we decided to develop the system and continuously receive feedback on it by conducting user studies from the visually impaired people. We decided to have a well-rounded group of people including both male and female and complete and partially impaired people. This way we would be able to accomplish most of the goals and try to help the community become more independent.

CHAPTER 3

RESEARCH QUESTIONS

The importance of a good, dependent and user -friendly navigation system has been well known. People have been dependent on navigation system for quite some time but the sudden need for them has risen in the recent years due to the increase in the social media networks and the mobile devices. It was also interesting to note how people started becoming more and more dependent on mobile devices. It is very important to keep in mind the disabled people and help them grow, personally and as a community. With that in mind, we wanted to see if we could try and solve some of the hardships that this community faces in their day-to-day activities.

There are many devices that can help visually impaired with navigation, but they are either very expensive or are an external device to be attached. This can prove to be a very complicated problem, as visually impaired people might not like to carry a cumbersome object with them.

The following points were important and kept in mind while trying to develop a navigation system.

1. What would be the optimal system on mobile devices for navigation for the visually impaired?
2. We wanted to design and develop and android system that could do the following:
3. An android based application
4. Give origin and destination location to help in navigation.
5. Navigation done for walking
6. Can enter location by keyboard or speech-to-text.
7. Use image comparison technology to detect obstacles in the way

However, it was crucial to look into the system such that we could get an easy to use and fast system. Image processing on such a small platform take a lot time so it was important that we do the comparison and object detection in the fastest manner possible.

HYPOTHESIS: At first we hypothesized that the users would not be interested in the kind of object in front of them and would be more interested in the fact that the app could detect an obstacle. However, with the studies we were proven wrong and had to change our hypothesis.

We also believed that most of the people would prefer an automatic voice synthesizer system than a manual one. It would be easier for people to access and understand it. Also, we assume that the users would keep the phone hanging around from their neck. This would mean any object detection would have to take place from the angle of the device hanging from the neck.

8. Can we choose one particular platform to design this system to help on a more global basis?

There are a few mobile applications available for iPhone. However, in many countries owning an iPhone is still considered a luxury. Also, iOS is a very complicated operating system with multiple permissions. The few number of navigation apps in android are either paid or don't have enough functionalities. Another reason for choosing the Android platform was the ease with which one can develop. The fact that a majority of mobile users use Android also did not hurt our idea.

Even though programming in iOS or android takes almost the same cost in terms of time or money, android technology is open source and more familiar by me. Also, it was easier to use, as there were fewer restrictions in terms of policies.

While trying to come up with solutions for these questions we came up with the following research questions:

RQ 1: How would gender, age or the level of blindness and the helping device affect their control of the system?

For all our user studies we tried to get a comprehensive group that would be from different demographic and include any and all genders, race, areas, etc. It would be quite interesting to see if any of the demographic conditions affects the way the participants actually use and access the navigation system.

RQ 2: How would users using existing apps compare Navigator with them?

All our participants were familiar with mobile devices and had either used or were using some navigation tool at some point. We also wanted to see how these users would react to them comparing these existing apps with Navigator. We were quite curious to see how their experience with these apps would impact them using Navigator.

RQ 3: Does it matter how big or small the button sizes are on the app?

Even though we had decided to design the system such that it can be accessed by voice command, we also wanted to include buttons, keeping the prior work in mind. However, we had no idea how big or small buttons would affect their decision to use the app again and freely and comfortably. This was an important detail to conduct a user study and do tests on.

RQ 4: Does the familiarity of the place also pose a problem or help while using a navigation app?

For some participants, the user studies would be conducted in unfamiliar places while for some they might be very knowledgeable about their environment. Having such distinct people on the spectrum would also give us definite answers about how experience enables in the user experience of a navigation app. Either they would not be completely dependent on the app or would use it frequently.

CHAPTER 4

USER STUDY 1: PILOT STUDY

There were three studies done to understand the features of the application designed. We wanted to see how to improve the functionalities so that we could add the desired characteristics based upon the feedback received.

For all the studies we wanted participants who could complete the following conditions:

1. They had to be partially or completely visually impaired. We followed the Illinois state's rule as the standard to accept the participant's blindness level.
2. They had to be English speakers.
3. They had to be 18 years of age or above
4. They had to be familiar with smartphones and how it normally functions.
5. Their participation was completely voluntary

Using any existing navigation system was optional and we wanted to get a good mixture of people who were already using some app to navigate and the ones who did not know. Hence, this condition was not a requirement while recruiting participants. We posted flyers and contact various blind schools in and around Illinois area. It was important that their definition of being blind was similar to what was considered in the state of Illinois. This helped us recruit some participants from the University of Illinois, Urbana Champaign itself (Disability Resources and Educational services) and the Blind services Association in Chicago. For the second users study we got some more volunteers from different blind school from St. Louis MO and Orland Park, IL.

The first user study was done to understand the needs of the users and the different ways the navigation system should work in various situations. We got a number of people to participate in the study from different demographics regions, occupations and age groups. It was also important to get an equal number of people with disability from a variety of spectrum in terms of blindness. We got some people who were completely blind and other who were partial while some who could not detect depth, etc. We had a total of 6 participants who volunteered for the study with 2 using cane and one using a guide dog as they helping device. Other felt comfortable enough to walk around without any help.

4.1 System and Interface design

The system accesses the Google Map JavaScript API online using an HTTP request. This helps load the Google map on the app. Different functionalities of the map, such as zoom; display of latitude (lat) and longitude (long) can also be retrieved from the library.

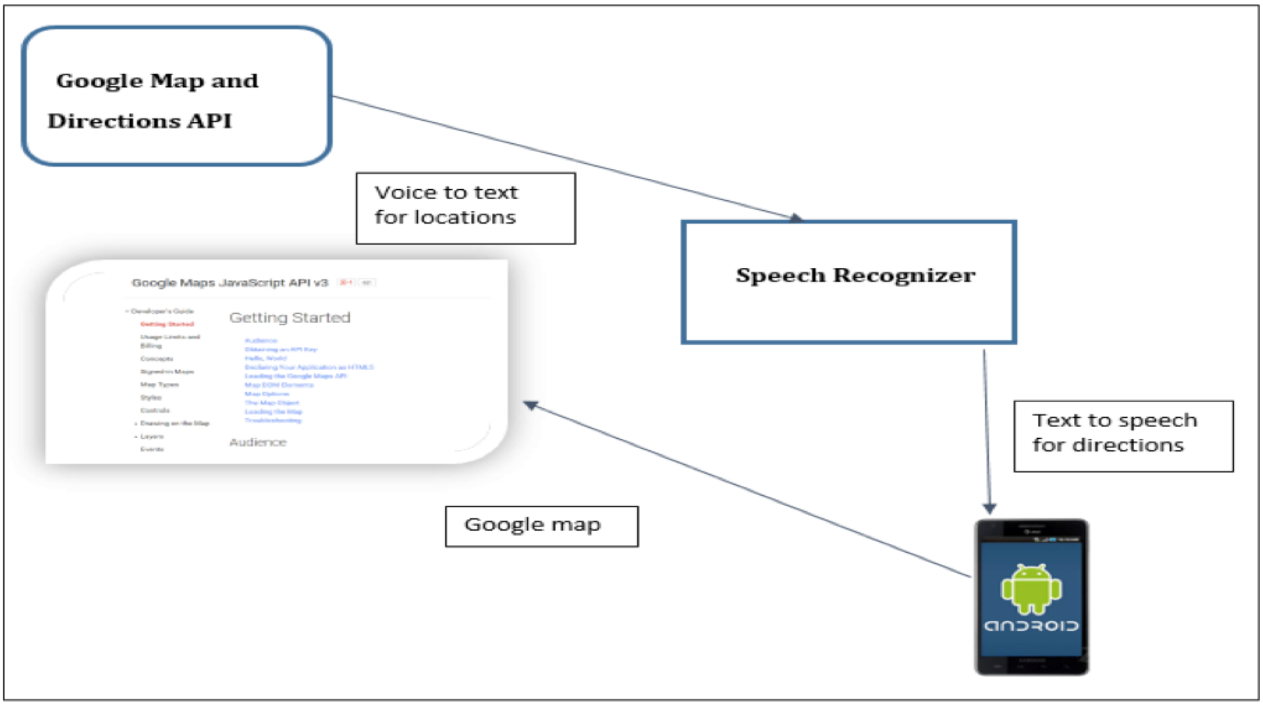


Figure 4.1: Approach

The Google map API was called to show the map and then we added various functionalities based on the feedback received by the participants and the prior work. Google directions API were used to get the map by giving the starting location and end point as the parameters. We could also filter the output by the mode of transport, time and distance taken and turn-by-turn instructions.

The time and distance given was then converted to the measure of unit we desired, in this case in minutes and blocks, respectively. It was also important to parse the data to JSON format to make it readable and easy to use and print for the user. Once the map was displayed, we enabled the zoom able and rotation features so that one could pinch and zoom on the map to go to any level of detail of the location. We also decided to use the default map type that the users would usually be familiar with.

The speech to text and text to speech synthesizer was added on top of the map to be able to access the location by voice commands, one did not need to manually write or swipe the location and could just say the locations and the map would automatically go to the desired location. For this system we used android TextToSpeech activity class. We could configure it for any language and any speech rate. Once the start and end location were chosen, the Google Directions API would be called to get the preferred route with all the filters. Using the graphics class in android, we would then draw on the map to show the desired route. The speech synthesizer would then pull the required instruction from the JSON file and speak as the participant starts walking.

The whole system has been conceptualized in such a manner that it is easy to use and has minimum processing. Using Google Map library helps us get a lot of information pertaining to the traffic and directions, which in turn gives us a more real time data. Google maps library is also easy to use and can be obtained easily by getting an API key. This key is unique for this project and hence, is secure. We decided to design a system overlapping the functionalities of Google Map which most of the people had heard of and/ or used.

4.2 Experimental design

This user study was conducted to understand the basic problems that the visually impaired faced in their life while navigating form one place to another. We decided to create a prototype with the basic structures that we thought would be useful for them. The design was supposed to be simple and easy to use without a lot of graphic designs and buttons on the screen. Since the completely visually impaired could not see the screen clearly, we also decided to use the mobile device's talk back option. This included the device repeating the name of every button the user clicked on the screen. This characteristic is available in almost every android phone and hence, we decided to use it. Not only would it repeat every button clicked, it would require one to press and hold a button for it be enabled. This would mean one could not press any button by mistake. They could hear what and where they are pressing and then click on the button.

The system was designed so that both, completely impaired and partially impaired people could use this system with ease. We decided to keep a large map with zoom able and rotation properties in the center of the screen. From the previous work done in this area, it was found that the users preferred if the system had huge buttons or images but as many as required. Hence we also decided to include fewer number of buttons- one to search for a location and one for using voice command for entering the locations and the third was used to start the navigation and it would give turn by turn instructions as voice command.

The buttons and the maps were placed such that there would be minimal movement from the user to access the system. We decided to keep all the movement to the right of the screen as most of the people are right handed and it would be easy for them to move on the right side of the screen. As shown in the following figures, the speech button, search button and the voice navigate buttons are all on the right side. Also it was decided that buttons would be placed on the top and button with the map taking the most space. With the zoom able property of the map, one could receive very detailed information on what the location they had zoomed on was.

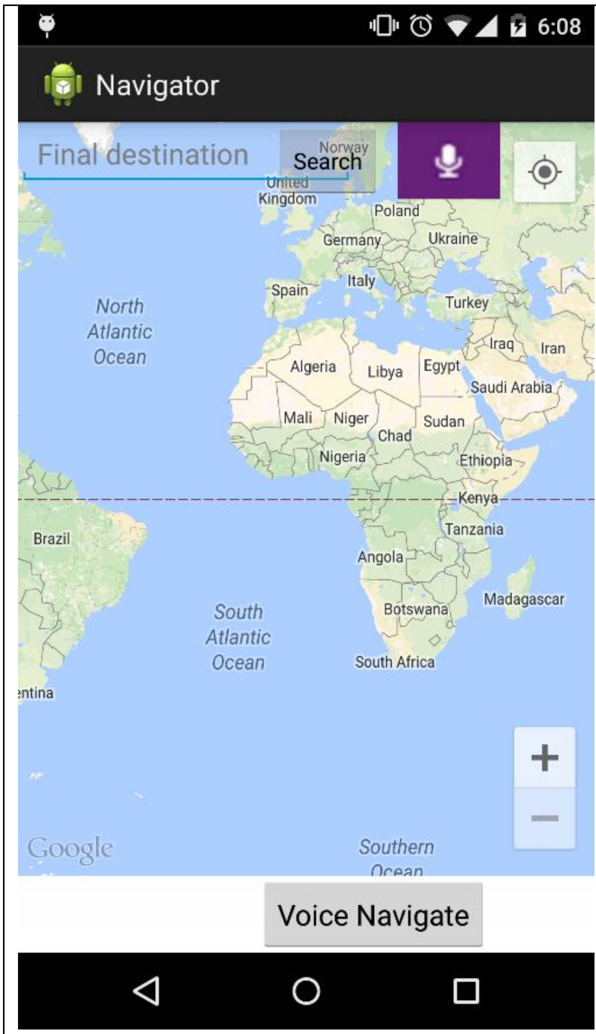


Fig 4.2: Enter location using keyboard or voice system

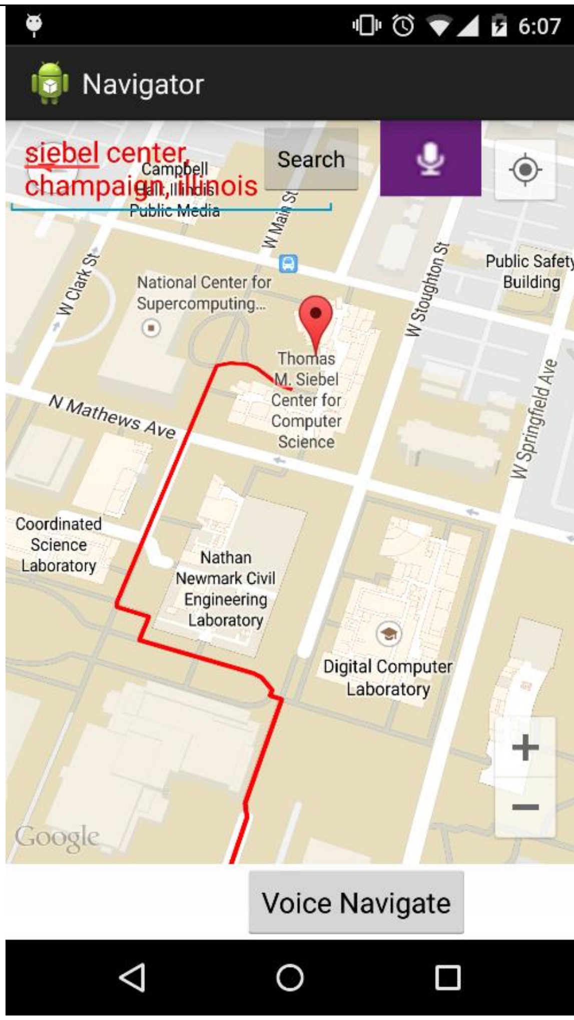


Fig 4.3 Route by foot from origin (green pin) to destination (red pin)

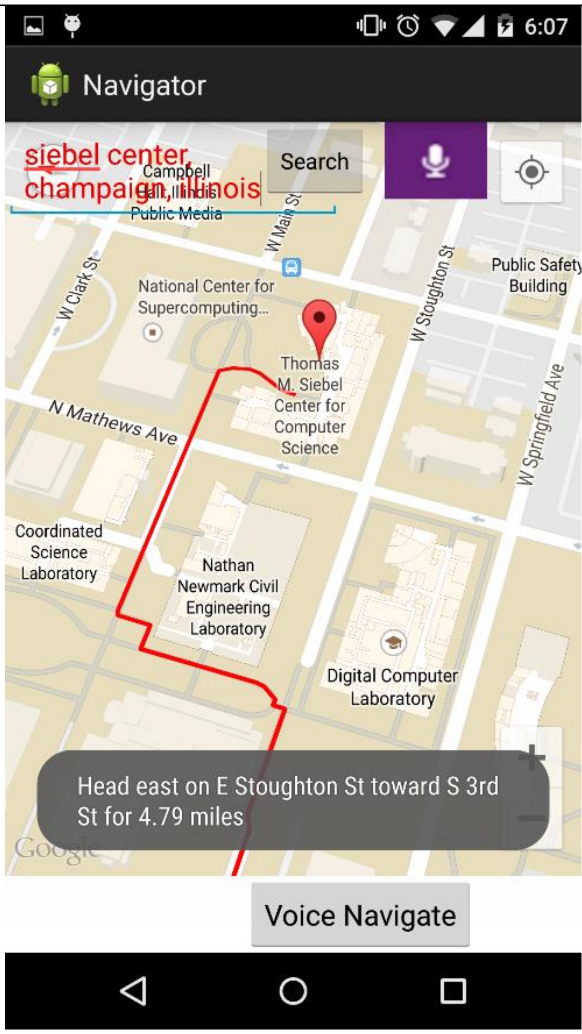


Fig 4.4 Shows the route (marked by red line) on the map
Clicking on the voice navigate button would start the turn-by-turn navigation

According to a preliminary survey and questionnaire that was conducted by some participants, we realized that the partially impaired people also would like to read text. This was particularly useful in situations where it might be too loud to hear and understand any of the voice commands/ feedback. This gave us the idea to also print out the instruction as the participant's walks.

To select a location one could do any one of the following things: use a keypad to write the address; use a voice command to give the address or click on the map. One could enable the keypad on the screen by simply clicking on the input box on the top left corner of the screen. To activate voice command, one had to click the icon that looks like a microphone. The icon that looks like a circle with spikes (top right corner icon) can also be used, but it would only give the current location. Once the address is type in, they had to click on the "search" button.

Using voice command to enter a location would be especially convenient for people who are completely impaired or if they are carrying multiple objects in their hand. They could click the voice command icon (looks like a microphone) to open the microphone and give the complete address of the location. The address would automatically be written in the input box and also repeated for the convenience of the users. If the address is incorrect, they could simply click the button again and speak the address clearly again.

The third option of clicking the map is especially useful for the people who are partially blind. For people who might not know the address and would like to look at the map and select, the option would be most helpful. One can simple zoom in or out of the map to select a location. The rotation property of the map also helps in changing the orientation of the map so that they can understand the map clearly.

Once the first location is selected, the map adds a green marker on the map to show that the location has been set as the origin. The destination location could again be added in either of the ways discussed above. The moment the destination is also chosen, the map adds a red marker to indicate the destination and also draws the path from the origin to the location. A red dark line indicated this. Currently we decided to give the rout only when a person walks as that is the most frequent and used mode of transport for the visually impaired. Once the route was added, the user had to click the voice navigate button to hear the turn-by-turn instructions.

Another aspect of this study that was important was the obstacle detection. We decided to keep the obstacle detection separate for this study, as we wanted the users to focus on one functionality at a time. Another reason for keeping them separate was that the obstacle detection was still work in progress at that time. The design for the obstacle detection contained just a camera view in the middle of the screen and a detect button on the top of the screen. This was done to keep the design somewhat similar to the design of the navigation screen.

The camera was kept in the middle so that it could focus on what was in front of the users. With the help of the surveys conducted previously, we found that the users liked the idea of the mobile device hung around their neck. This would free the hand that would otherwise be holding the device. The user had to click the detect button to start the detection and the camera would continuously start taking pictures. If the camera detected an object in the path of the user it would start vibrating. The vibration was chosen as the form of feedback because it would be crucial in situation where the users could not hear any sound given.

The environment for the testing was chosen to be a location the participants were familiar with. This was done because we wanted the participants to use the app and give their basic feedback. Also the location was convenient for most of the participants. This was chosen so that we could have a common location to test on. For the participants in Champaign we chose the Disability Resources and Educational Services (DRES) building while for Chicago participants, the Blind Service Association (BSA) was chosen. The study was designed to last a maximum of one hour. For the object detection study, we decided to manually create path using some objects that were available in the room and decorated the path with objects higher and lower than them. Thought this was manipulated for all the location, they were kept consistent for the participants in the same location.

We had a total of 6 participants, who volunteered for this study, with 4females and 2 male. Among the participants we had 2 between the ages of 18 and 30 and 2 between 50-65 and 2 above 65 years of age. Among the participants we also had 2 people who were using the cane, 3 people who never used any helping device and one who had a guide dog to help him around. Having people with any and all kind of experience also gave us a better perspective on how different people would access the system.

The following are the demographic details of the participants

User	Navigation helping aide	Visual impairment	M/F	Age	When was the vision lost?
Cha1	None	Partial	F	18-30	Birth defect
Cha2	None	Partial	M	18-30	At the age of 10
Chi1	Walking cane	Complete	M	> 65	Birth defect
Chi2	None	Partial	F	50-65	Birth defect
Chi3	Walking cane	Complete	F	> 65	Birth defect
Chi4	Guide dog	Partial	F	50-65	Eye disease diagnosed at 7, lost eyesight by age of 40

Table 4.1: Demographic details of participants User study 1

As we can see the results that were received are based not only the level of blindness but could also be affected by the amount of time that they were visually impaired. People who were visually impaired due to a birth defect were more used to their disability and could have workarounds on how to navigate. They would also be more comfortable and have more practice with any existing technologies.

4.3 Procedure

Once we met with the participants, it was very important to make sure they were clear about the study. With this in mind, the participants were asked to sign a consent form that would give them the different rules and regulations that were involved the user study. For the people who could not see at all, the entire consent form was read. It was also important to make sure that the participants understood that this was a completely voluntary study and they would be paid a compensation for their help and time.

Once the consent form was signed, we asked the participants to complete a survey and then use the app to give us their feedback. The survey had questions about their demographic such as, their age and their occupation. The questions asked were also about how often they travelled by themselves and how they travelled, i.e., by walking, car, with a guide dog or a cane etc.; What problems do they usually face while navigating and while detecting and avoiding obstacles; Whether they use some mobile device and any particular application to help them navigate or detect obstacles. The questions were designed in a way to understand the problems that the participants faced in their daily activities.

The survey and interview forms have been attached to the appendix. [Appendix A and B]

Once we received the completed survey the participants were then given a tutorial of how to use the application and the device. They were also asked to use the device and get a feel of the applications by themselves and any questions asked by them were answered.

Once the different forms were completed, the participants were asked to navigate from one place to another to analyze the navigation part of the system. The origin was the current location and the destination was a place of their choice. The origin was already set for them and the destination was to be added either by a keypad or the voice command or by simply touching the map. Once the route was highlighted, they had to click the voice navigate button to hear the all the instructions. We did not ask them to actually use the app outside.

They had to only listen to all the instructions from the start to the end of the route. This also helped us analyze how comfortable they were with the whole speech to text and text to speech system. Once the system started speaking the turn-by-turn navigation they could not only test the speech technology that the system uses but also other factors such as the speed, the dialect and the accents used. The distance was measured in steps, which was considered a standard unit based on the research.

Once the instructions were heard, the object detection technology was tested. A path was created indoors that could detect any objects in their way. The objects that were put in the designed route were of different shapes and sizes so that we could analyze the spectrum of the different obstacles. Some of the objects that were used were of different heights while others had different shapes. We also made the participants walk with us walking towards and away from them to understand how the system might work in real life situations. This test was done with the different helping instruments that are used by the blind- e.g.: cane or blind dog. For the object detection study, the users were just asked to walk around the path with the helping device of their choice and see if the system could detect the obstacle at the speed they were comfortable with.

Once all the studies were completed, they were asked to complete an interview that asked them about their experience using the system and what they felt could be changed. During the entire process of the study, any and all feedback was recorded and the interview asked them specific questions about their experience such as, whether they would recommend this app to their friends or if they would use it themselves. Once the interview was conducted the participants were thanked for their time and given the compensation that they were due.

We also had some humans walk towards and away from them to mimic the situation where they might be around a huge crowd. The paths were also designed so that they could also tested when they are in an environment with sparse objects and one where the objects are close to each other. The object detection had to be activated in any and all situations and keep them from bumping into them.

The idea was to design a path using the objects that were in the room so that they could mimic the outside world as close as possible. We used different objects to have them so that they could be at a height than average person’s height and lower than them. The following paths were designed in different places in Chicago and Champaign and were used only for object detection.

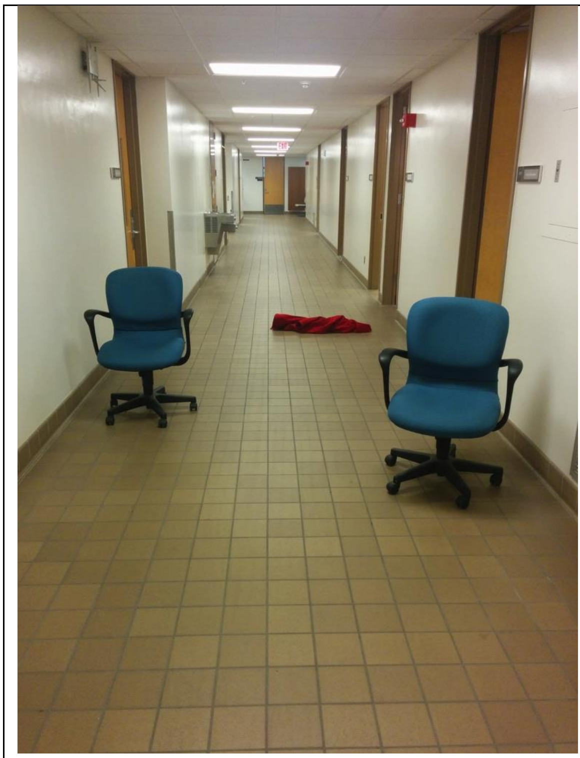


Fig 4.5: First path in Champaign for obstacle detection study

Fig 4.6. Second path in Champaign for obstacle detection study

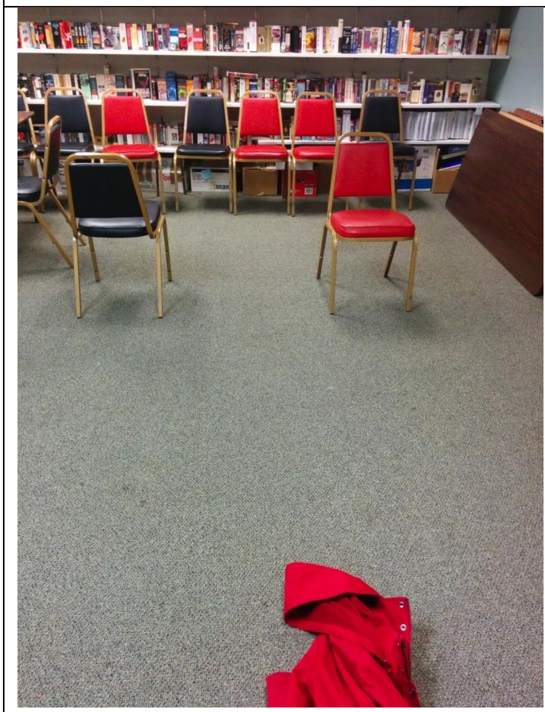


Fig 4.7. First path in Chicago for obstacle detection study

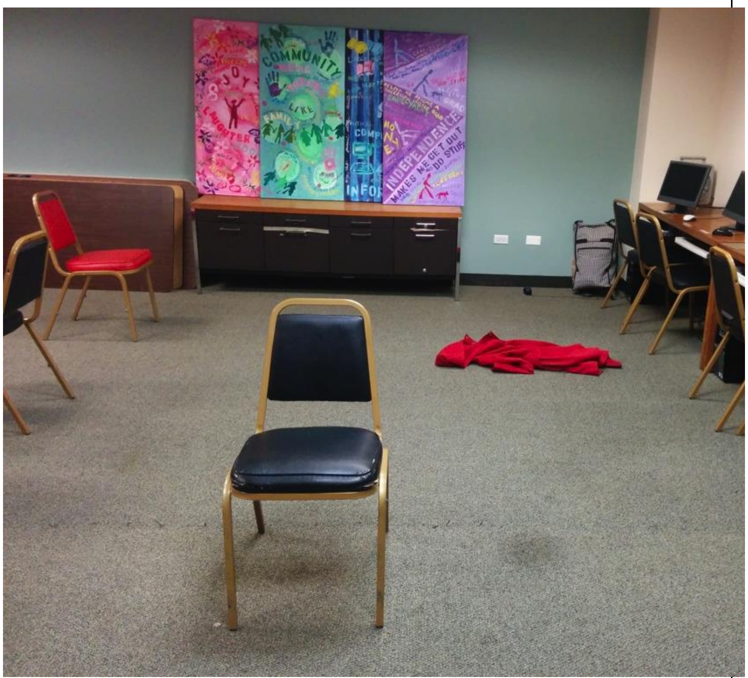


Fig 4.8. Second path in Chicago for obstacle detection study

4.4 Results

This study was designed to just get a basic idea of how the visually impaired people would interact with an android application that could have the basic features that we learnt from the previous research and other conversations and surveys. We tried to imitate some existing applications that the people are familiar with and added our functionalities on top of it so that they are familiar with the interface and it is not a huge change. All these results were received either by answering questionnaires or through the interviews after them using the app.

4.4.1 Navigation results

User	Helping aide	Visual impairment	M/F	Age	Feedback
Cha1	None	Partial	F	18-30	Talk back option Distance should be measured in miles or blocks
Cha2	None	Partial	M	18-30	Talk back option
Chi1	Walking cane	Complete	M	> 65	Talk back option
Chi2	None	Partial	F	50-65	Talk back option Distance should be measured in miles or blocks
Chi3	Walking cane	Complete	F	> 65	Talk back option Distance should be measured in miles or blocks
Chi4	Guide dog	Partial	F	50-65	Talk back option Distance should be measured in miles or blocks

Table 4.2: User study 1: navigation results

Based on the questionnaire and the feedback received during the study, we found out that participants who were partially impaired liked the idea of a map while those who were completely blind did not care much for it. Out of the 6 participants in total we had 4 who were partially impaired and they preferred no map at all and have only buttons, as they could not see the map. 5 participants also felt that having texts instead of a complicated map is much better as in they would not be distracted with other items on the map. Also, it would be difficult for people who are completely impaired to use the interface if there was a map, as they would have to be precise while clicking on the buttons of the interface.

When asked about the interface, the most common feedback, by all 6 people, was to have bigger buttons instead of having such small ones. As someone who is visually impaired it would be difficult for him or her to be precise and click on the button. Having big buttons or contrast in color can help both, the partially impaired and completely impaired to access the system easily. Also, having the talk back option on the button was quite helpful in situations where one could not see the screen and they could feel the area and know which button they could click on.

Another feedback received from the participants, by all 6 people, was to have a talk back option when they use the microphone to set the location. Currently the system would convert whatever was said through the microphone into text and automatically put it in the textbox location and search for it on the map. However, the users felt, they would like additional feedback to know if the system correctly understood the address given by the users. When asked about how comfortable they were with the speech to text conversion in general, most of the participants were comfortable with it and gave us positive feedback.

Four among six users gave us the feedback for the navigation part of the system - they wanted the distance to me measured in some other unit than in steps. For most people, a step is something that is not a standard they are used to. In fact most of them were more familiar with blocks or miles. Also, each person’s step would be of different length and the system would have to first understand the length of the user’s step and calculate the distance accordingly. Another problem with steps was that it would be difficult for the user to keep in mind how many steps he had taken already. To ask the user to keep counting the steps is an additional feat, which increases the cognitive load on him.

4.4.2 Obstacle detection

User	Helping aide	Visual impairment	M/F	Age	Feedback
Cha1	None	Partial	F	18-30	Have some standard objects pre-determined
Cha2	None	Partial	M	18-30	Have some standard objects pre-determined
Chi1	Walking cane	Complete	M	> 65	Different tunes and tones Have some standard objects pre-determined
Chi2	None	Partial	F	50-65	Different tunes and tones Have some standard objects pre-determined
Chi3	Walking cane	Complete	F	> 65	Different tunes and tones
Chi4	Guide dog	Partial	F	50-65	Did not care much about the object detection

Table 4.3: User study 1: obstacle detection

When it came to the object detection part of the system, most of the users gave us positive comments of how the object detection worked. They liked the vibration aspect of the system and felt it was important that it also speaks in cases where they might miss the vibration. A major setback in the current system was that the system was very sensitive; it could detect objects at a much farther distance than what most people would've liked.

The participants who were above 50 years of age and were used to travelling with canes gave us the idea of using different tones and tunes to detect different obstacles. Right now the system had standard vibrations for all objects irrespective of the height it was located. It would be beneficial for the users to have different musical tones and vibration so that they are aware of the objects in their path. It is crucial to give as much information as possible about the environment to the visually impaired so that they can have spatial updating and understand the environment better.

Having some standard objects likes electricity poles and trashcans detected quicker would also them change their route if required. Also detecting objects at night and ice is also something that can help them further. We found that the users automatically changed their direction based on where the vibrations were coming from. If the system told them to turn left or right or just stopped vibrating once they avoid the object, they might feel more secure with the app.

All these feedbacks were collected during the interview or while they were using the app. The feedback could have been different based on the level of blindness, their age and also the level of experience with technology based on the age there were visually impaired. People who have had a birth defect and lost their eyesight might be more familiar with the navigation technologies than others. On the other hand, it is also possible that people who are above 50 might not be as confident as younger people with the current technologies and electronic devices. However, we are under the assumption that all these people are equally experienced irrespective of their disability history.

4.5 Summary of results

Based on the feedback given to us by the users in the first study, the biggest feature that had to be changed was the button size and the maps. It was important for the maps to be smaller in size or not be present in the interface, as the completely blind people did not care much for it. Having bigger button would also help them easily interact with the interface. One does not have be specific and click the button. The area in general of the screen would be more generic to work with.

We also learned that the users really liked the idea of having a speech to text interface and vice versa. Since they are already used to talking to a device instead of clicking the button, having talk back options for this interface would convenient. It was also interesting to see how comfortable the users were with smart phones just by this option even though there were no physical buttons to touch and feel the interface.

The object detection part was something that all the users were very excited about. Since none of the existing navigation system has this feature, it was something that made us different. Though the system was very sensitive right now and could detect objects a few feet apart instead of just a few inches, it was still something that was readily accepted by the people.

Another interesting thing that we noticed was that people who used cane as their helping device were more interested in the object detection part while people who used a guide dog were more excited by the navigation system. This led us to believe that we might be able to solve our first research question of how people with different genders and helping devices might react to the system.

Based on the results, we had to come up with more studies to improve the design of the app and include functionalities that were recommended. With the feedback in mind we developed another design for Navigator, and decided to compare it with the existing interface based on the interface design and the navigational functionalities.

CHAPTER 5

USER STUDY 2: COMPARISON OF INTERFACES (GOOGLE MAP VS. NAVIGATOR) - BASED ON THEIR INTERFACE DESIGNS

As discussed, the pilot study was conducted to understand and analyze the views of the visually impaired for the current app. The current app uses the features of Google Map and has been overlay with our buttons to customize to the needs of the visually impaired. We wanted to conduct another user study to improve the functionalities of the system and make it better to use. This study mostly concentrated on the features and characteristics of the navigation part of the system. The feedback from user study 1 was taken into consideration while developing a new version of the Navigator. This was then used in the second user study.

The study involved the participants to complete a survey, an interview and then use the Navigator to navigate from one pace to another. The idea was to understand how the new characteristics helped in navigating the participants from one place to another. The participants were asked to sign a consent form that gave us permission to record their voice during the study and told them about the procedure of the study. Once the consent forms were signed, the returning participants were taken to the actually use the Navigator while the new participants were asked to complete the survey with the same questions as in the study 1.

For this study too we decided to use the same strategy of making phone calls, emails and flyers to attract volunteers for the study. We got 12 participants in total with 5 being the same who participated in the first study. This time too we got people who were comfortable using a cane or a guide dog to travel and some who did not need any such help. All the participants were between the ages of 25-65 years.

The demographic details of the participants are as follows:

User	Visual impairment	Gender	Age	When was the vision lost?
Cha1	Partial	M	25-35	At the age of 10
Cha2	Partial	M	35-50	At the age of 35
Chi 1	Partial	F	50-64	Birth defect
Chi 2	Complete	F	>64	Birth defect
Chi 3	Partial	M	>64	Birth defect
Chi 4	Partial	F	50-64	Eye disease diagnosed at 7, lost eyesight by 40
SL 1	Complete	F	35-50	At the age of 30
SL 2	Partial	M	>64	At the age of 60
SL 3	Partial	M	35-50	Birth defect
SL 4	Partial	F	50-64	Birth defect
OP 1	Complete	M	25-25	At the age of 20
OP 2	Complete	M	50-64	Birth defect

Table 5.1: Demographic details of participants: User study 2

5.1 Experiment design

The first study was a comparison on the button size of the system. This was based on the feedback we received that the size of button would affect the system and increase the comfort level of the participants. The participants were given two interfaces- one with big sized buttons and no Map, which is called the Navigator interface, while the other had small buttons (close to the original interface) with a large map, which will be known as the Google Map interface. For the interface with small buttons, the interface was the same as the one used for user study one and used the Google Map. The idea was that the buttons were all placed on the right side of the screen with a giant map in the middle.

One very important feedback we had received in the first user study about the interface design was that the map was almost useless for people who were completely visually impaired. For them the button size had to be bigger so that they did not have to worry about clicking on the map instead of the buttons. The size would also help them not worry about the exact position of the button and they could click anywhere in the vicinity of the button. This feedback helped us design the second interface where we decided to get rid of the map completely. Though the partially impaired people used the map, they were also not always using the map and were more dependent on the voice navigation or the text that was shown.

The design of this interface was done such that the screen could be split into panels and each horizontal panel was a button. This would require the user to click anywhere on the screen, right or left without worrying them to be precise. The first panel was the input box and we completely got rid of the microphone icon for the speech to text. Instead we decided to add the same functionality to the text box. If the user clicked on the textbox once, the keypad would be enabled and if they pressed and held the text box the microphone would be activated. The way to enter a location was the same as in the first user study.

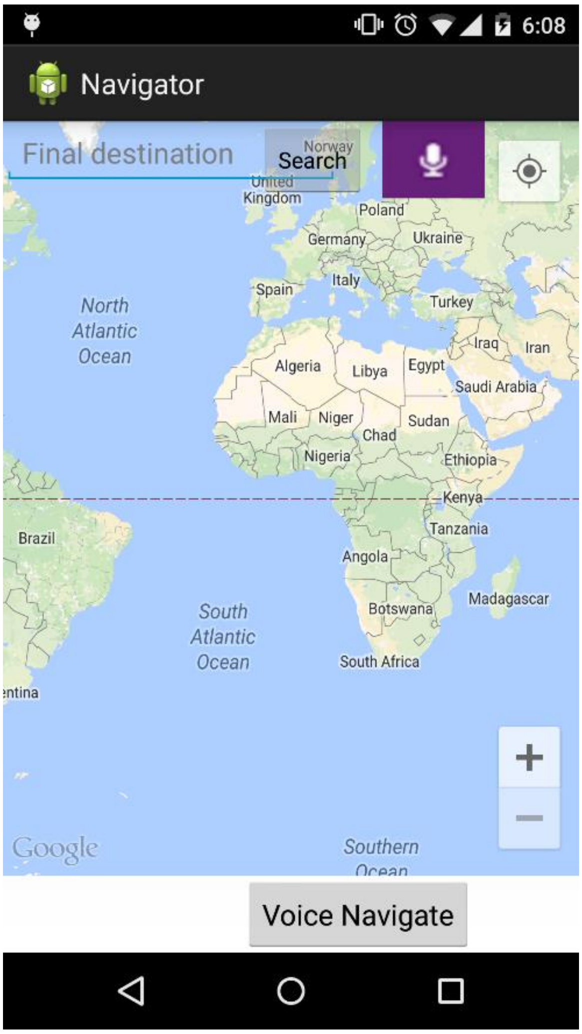
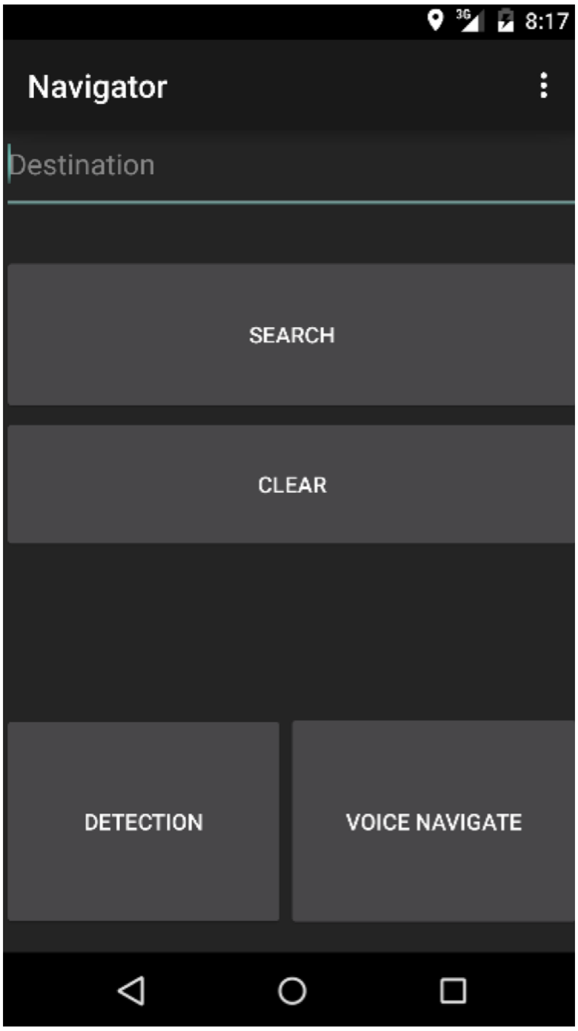
Another feedback that was consistent from all the participants in the previous study was the absence of a clear button. We decided to add a clear button right below the search button so that they could clear the screen and start the system again. Below the clear button was the camera that would be used to detect the obstacle. Though we would have liked the camera to be after all the button, it was important to place it in the middle of the screen so that it could detect objects right in front of them.

Below the camera we decided to place both the voice navigate and detect button. We decided to avoid having them in separate panels as the voice navigate button could have been clicked multiple times. We wanted to avoid the overhead of them trying to precise for a button that they would use regularly.

We also decided to add a setting button on the top right corner of the screen that would define the different set of paths that would be used for this study. We shall discuss the function of these sets in the next study.

As seen below to the left we can see the Google Map interface, which was used in the first user study and the Navigator interface which was designed based on the feedback received from the first study. The biggest difference in both the interfaces is the absence of the

Google Map and inclusion of bigger sized buttons. The position of the buttons has also been changed such that all the buttons are below each other instead of side by side.

<table>
<tr><td>Google Map interface</td><td>Navigator interface</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Fig 5.1: Google Map interface (Small buttons and a map)</td><td>Fig 5.2: Navigator interface (Big buttons with no map)</td></tr>
</table>

5.2 Procedure

Once we met with the participants they were asked to sign the consent form that would give us permission to record anything and everything they say. This consent form also gave those different rules and regulation that were supposed to be followed during the study. This was similar to what we had done in the first user study.

For this study, the participants were then given some time to make themselves comfortable with the interface and the position of the buttons. All the participants were given both the interfaces once after the other. Once thy understood the design of the new interface, they were asked to click on the “Clear”, “Search” and “Voice Navigate” button in the given order. The number of errors made while trying to click on the three buttons was then noted. We also noted the time taken to complete the task.

5.3 Results

5.3.1 Anova to compare the effect of interfaces, blindness level and gender on the number of errors made.

We calculated the ANOVA with the 12 participants where each participant is tested on two interfaces- Google Map interface and the Navigator interface. There are 2 between subject variables- Gender and Blindness level and one within subject variable- Button size However the Anova is calculated between 3 independent variables- gender, blindness level and button size with the number of errors as the dependent variable. The results were as follows:

	df	Sum of Squares	Mean Squares	F Value	Pr (>F)
Gender	1	7.42	7.42	1.14	0.30
Blindness Level	1	13.22	13.22	2.03	0.17

Table 5.2: Anova to compare the effect of interfaces, blindness level and gender on the number of errors made.

Table 5.2: (contd.)					
Button size	1	30.73	30.73	4.71	0.05
Gender and Blindness level	1	2.84	2.84	0.44	0.52
Gender and interfaces	1	0.87	0.87	0.13	0.72
Blindness level and interfaces	1	0.48	0.48	0.07	0.79
Gender, Blindness level and Interfaces	1	0.18	0.18	0.30.30	0.87
Residuals	14	91.33	6.52	0.17	

With this data we can clearly see that the interface is affects the number of errors made. It also depends on the size and we can statically prove that the hypothesis that all components are equally important in making a difference in the number of errors is incorrect. Only the interface shows significant difference in the number of errors made. The alternate hypothesis can also be that the interface is linearly dependent on the number of errors made by the participant while completing the task of using the interface.

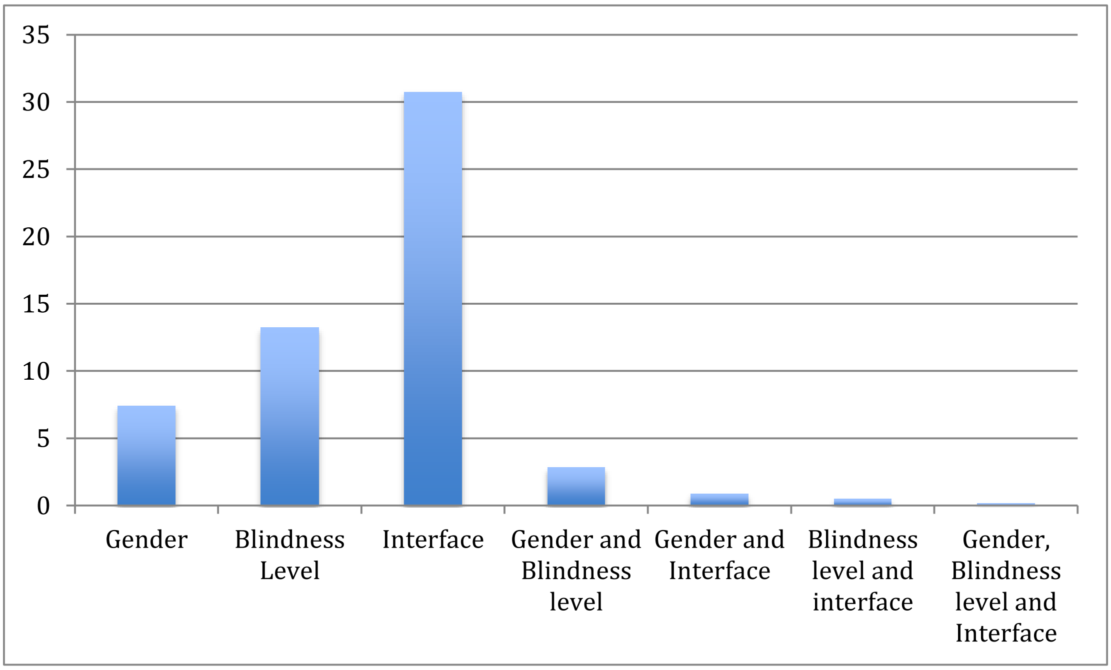


Fig 5.3. Relationship between all the three factors to determine the number of errors made.

The tables of means were also calculated with the gran mean as 3.36. [Appendix C].

5.3.2 Comparison of interfaces based on the number of errors made

	Number of errors made in	
User	Navigator	Google Map
Cha1	3	4
Cha2	2	2
Chi 1	1	2
Chi 2	5	11
Chi 11	0	2
Chi 12	4	9
SL 1	3	3
SL 2	2	4
SL 11	2	6
SL 12	0	2
OP 1	2	5
OP 2	2	4
Mean	2.17	4.55
Standard Deviation	1.47	3.05
Standard Error of mean	0.42	0.92
N	12	12

Table 5.3: Results comparing Navigator and Google map interfaces based on the number of errors made

The two-tailed P value equals 0.0246

By conventional criteria, this difference is considered to be statistically significant. (Because $p <= 0.05$)

The mean of Google Map interface vs. Navigator interface equals -2.38

95% confidence interval of this difference: From -4.42 to -0.34

$t = 2.4206$

$df = 21$

Standard error of difference = 0.983

With the given statistical analysis we can see that there is a significant difference in the size of the buttons. According the P value, we can see that people found the Navigator interface to be more accurate and more comfortable to use than the Google Map one. Not only could we prove this by the time it took for them to complete a task but the number of errors made while doing a task was also significantly lower than for Google Map interface

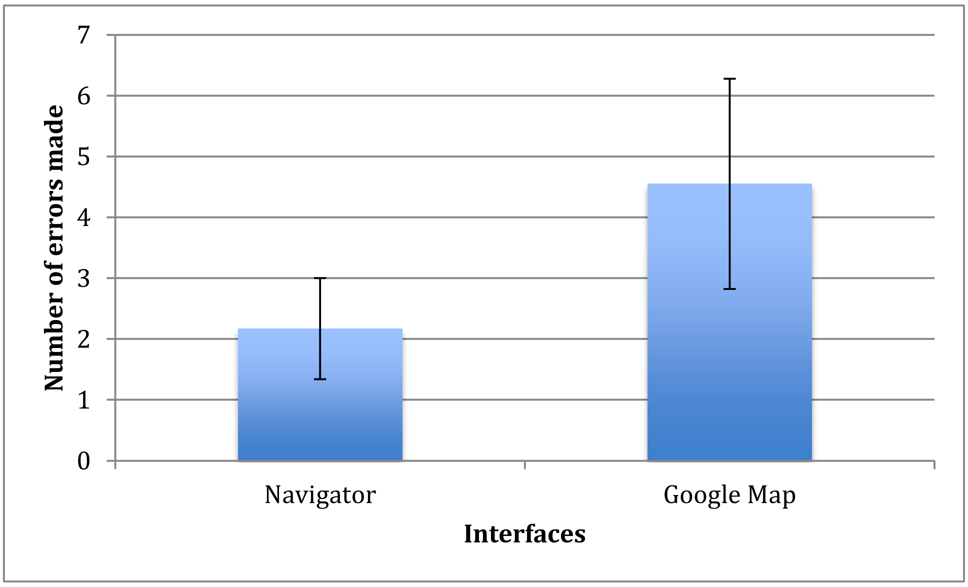


Fig 5.4 Comparison of Navigator and Google map interfaces based on the number of errors made

This graph has been drawn with 95% Confidence intervals for the error bars. We can clearly see that the number of errors made in the Google Map interface is significantly higher than the errors made with the Navigator.

5.3.3 Comparison of interfaces based on the number of errors made and gender

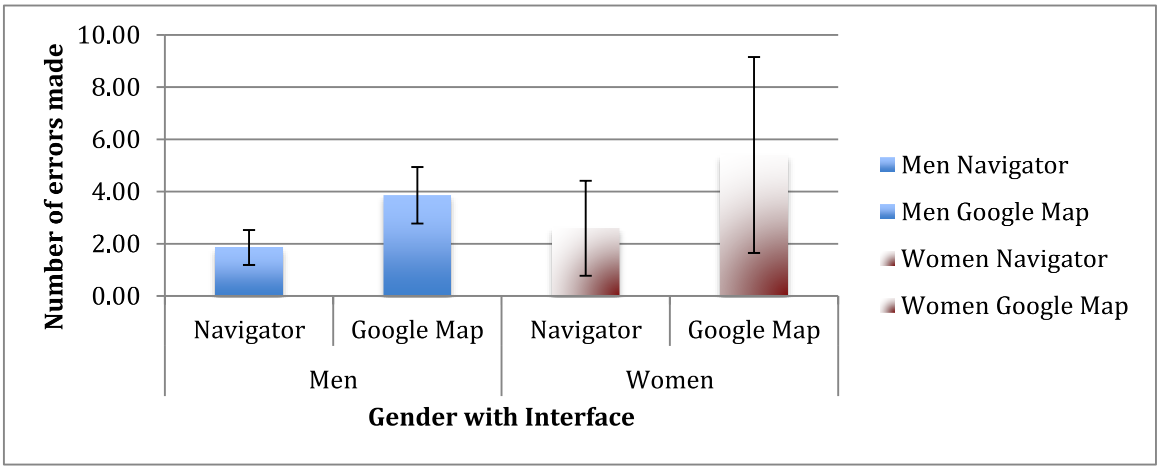


Fig 5.5: Comparison of Navigator and Google map interfaces and the number of errors made, based on the gender.

The p value for men between the interfaces is 0.012. According to the criteria, we know it is statistically significant. We can thus prove, that men made fewer errors while using the Navigator interface

The p value for women between the interfaces is 0.2376. According to the criteria, we know that this is not statistically significant. It is quite interesting to note that women had no trouble doing the task with either interface.

5.3.4 Comparison of interfaces based on the number of errors made and blindness level

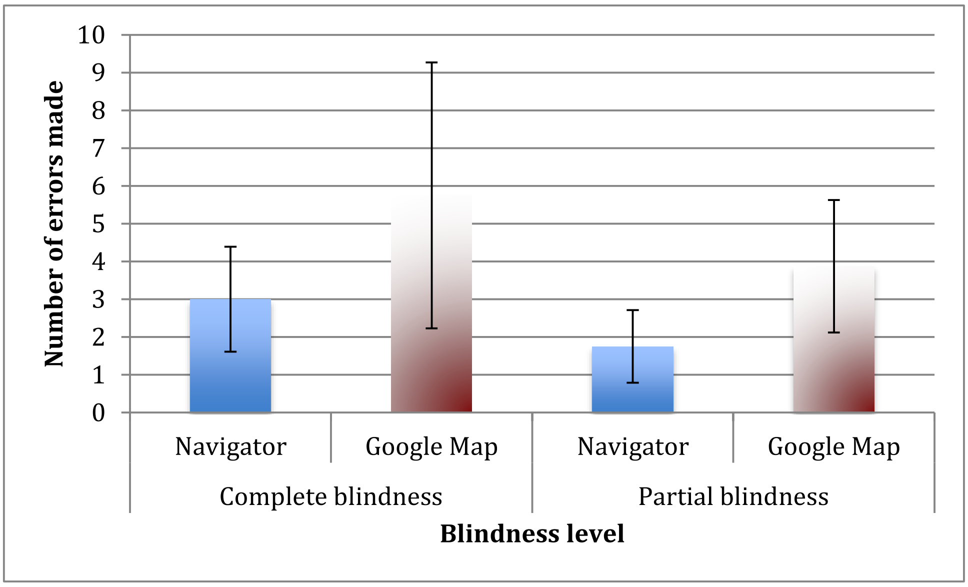


Fig 5.6: Comparison of Navigator and Google map interfaces and the number of errors made, based on the blindness level.

The p value for people with complete blindness is 0.2291. We know this is not statistically significant. Even though the number of errors made in Google Map interface was higher than with Navigator interface, statistically there is no difference.

The p value for people with partial blindness is 0.0619. This is not statistically significant and we can see that people with partial blindness would not require a huge difference in the interfaces to avoid making a huge number of errors.

5.4 Summary of Results

There were a number of tests done to analyze the number of errors made while accessing the interface. These results could help us understand which factor was the most involved in making an error. The first test involved calculating the number of errors made based on the button sizes the p-value was 0.0246. We can statistically prove that people were able to make fewer mistakes with bigger sized buttons. We can attribute this to the fact that they did not have to be accurate and precise while clicking a button and had to click on a general area.

The second test involved a bit more demographic details and how that resulted in the number of errors made for the task of navigating and understanding the interface. Based on gender the p-value was 0.012 for men and 0.2376 for women. This was an interesting study to see the number of errors each gender could make based on the interface. It was statistically found that men made fewer errors while using the interface in Navigator interface while there was no significant difference for women. This can be seen as an example of how the mind perceives an interface in each gender and how delicate and precise movements are much easier for women to make than men

The third test was done to see how the degree of blindness in a person could affect their ability to use an android device and the app itself. Based on blindness level the p-value was 0.2291 for complete blindness and 0.0691 for partial. This test was done to see if there would be any significant difference in the number of errors made based on the blindness level of a person. Even though partially impaired people can see the screen a little, most of them used the talk back option to access the system and hence the number of errors made by either group is not important.

Finally it was important to see how all these factors could affect one’s way to operate the app and approach any task given to them. On comparing how blindness level and the gender can affect the number of errors made the p-value was 0.87. We could clearly see that the only the button size significantly affected the number of errors made. As expected from our hypothesis, more screen space would mean easier approach to the navigation tasks. Also, as time goes, each person gets more and more familiar and accustomed to the positions of the buttons.

CHAPTER 6

USER STUDY 3: COMPARISON OF INTERFACES (GOOGLE MAP VS. NAVIGATOR) - BASED ON THEIR NAVIGATIONAL GUIDANCE

In the first user study we had seen that there were a number of issues that the participants had faced on the Google Map interface. Based on their feedback we changed the interface and designed and developed our own interface keeping in mind the different requirements for the visually impaired. However, it was important to examine how the navigational guidance was improved in the Navigator than the Google Map interface.

6.1 Experiment design

This study involved the participants actually use the system and compare it with some existing navigation tools, like Google Maps. . We used the same interface that was described in the user study two. For the actual comparison the participants were asked to follow pre-determined routes that could be changed and selected from the settings that was added in the top right corner of the screen. Each set consisted of an origin and destination and had different routes to reach the destination from the origin. There were different waypoints that the users had to cross before reaching the destination. The origin and location were famous landmarks so that people who were familiar with the area would know easily. For people who were not from the area, it did not matter what was the origin and we could easily identify how much they were actually helped by the systems.

To improve the functionalities of the system from the first study, we not only tried to change the current functionalities but added new features for the ease of the participants. Instead of measuring distance in terms of steps, we decided to measure distance in terms of blocks. It was found in the previous experiments that people preferred to use miles or blocks, which was easier than remembering the number of steps taken or required to take. Another important aspect of the app is the speech to text system. It was important for the participants that there be a repeat option to hear the most recent instruction again so that they can be sure they did not miss out on anything. This option was not available in Google Maps and was hence, added in the new version of Navigator. Clicking on the voice navigate button would repeat the previous instruction and as the participants crossed the distance given, the instruction would change to the next step. However the participants had to click on the button continuously to know the next step instead of automating it. The idea behind this was so that the repetition would be a choice of the user.

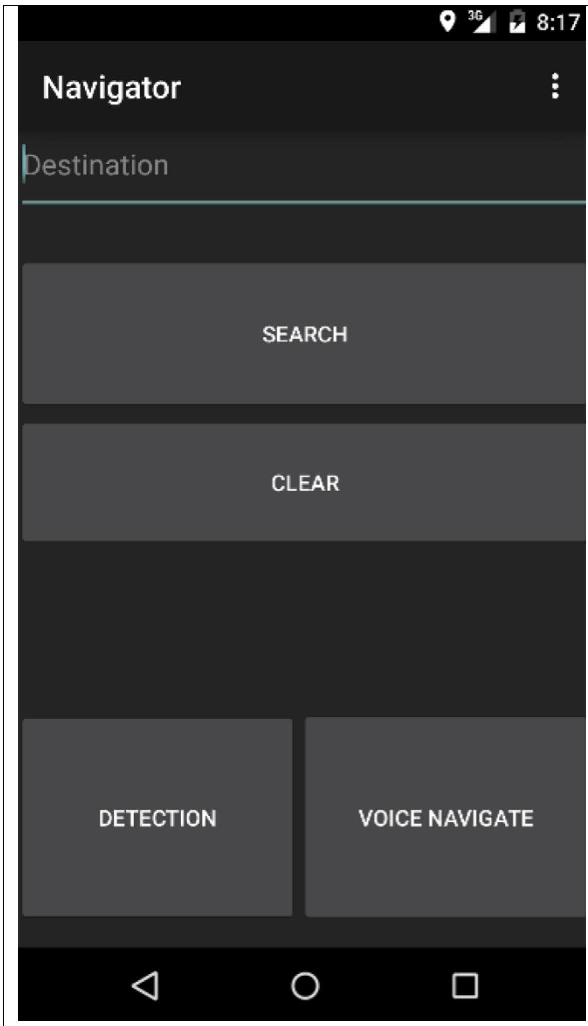
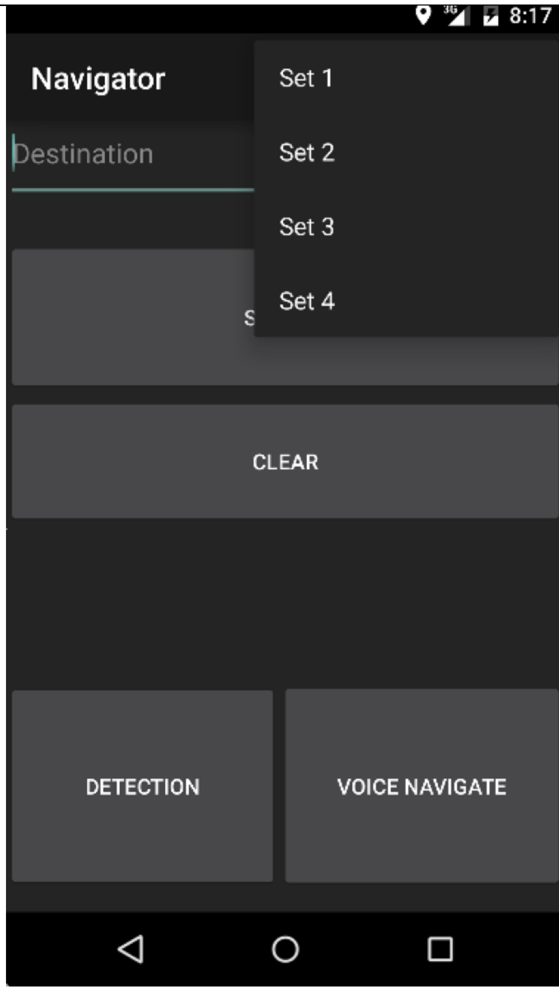
	

Fig 6.1 Interface for user study 3	Fig 6.2 Sets for the path can be chosen from the top right button

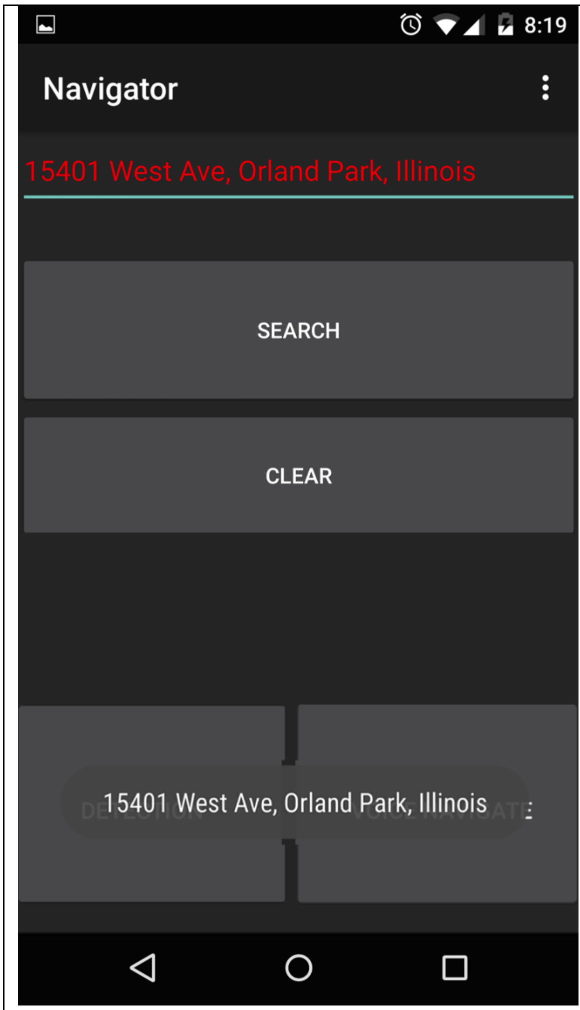


Fig 6.3: Select a set to start and a specific route is selected and the destination is entered automatically in the text box.

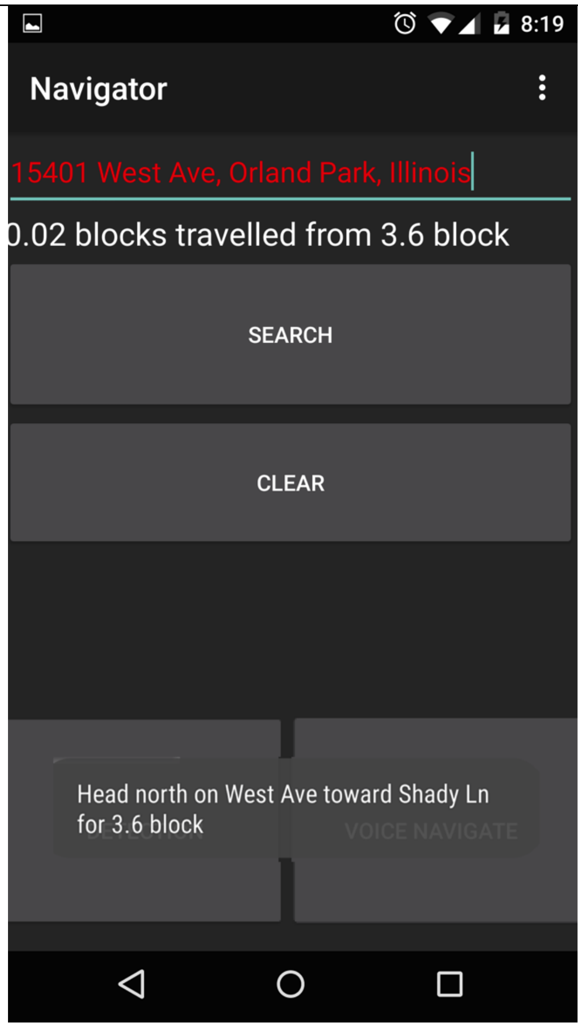


Fig 6.4: The navigation starts with the distance travelled also being shown as you start walking

6.2 Procedure

As we met new participants we asked them to complete the survey that the existing participants had completed in the first user study. Everyone had to also sign the consent form that was similar to the one used in the first one.

Each participant was supposed to use the navigator first and then use Google Map to travel the routes. The participant while using the Navigator (Nav) and Google Map (Google) alternatively too completed the routes alternatively. For e.g.:

1. Participant 1: Google + Set 1 and Nav + Set 2 —> Nav + Set 3 and Google + Set 4
2. Participant 2: Google + Set 2 and Nav + Set 1 —> Nav + Set 4 and Google + Set 3
3. Participant 3: Nav + Set 1 and Google + Set 2 —> Google + Set 3 and Nav + Set 4
4. Participant 4: Nav + Set 2 and Google + Set 1 —> Google + Set 4 and Nav + Set 3

Before the participants actually walked the route, we asked them to tell us what route they would take based on the knowledge of the area. They were also asked to discuss any shortcuts they would take which would help us get a better idea on how much they are aware of their surroundings. This knowledge would later be used to calculate the difference in the routes that they had expected to take and the route that they actually took. Here, we tried to get a good mixture of familiarity of the paths among the participants.

The paths chosen for this user study were chosen for the same reason as in user study 1. However, in this study we decided to choose familiar and unfamiliar paths to find the difference in the way the user would respond in such situations. The start and end locations were kept the same for all the participants, but the route to be taken for each of set of navigation system was chosen individually.

Each participant had to go through all the set of points and navigation system based on the combination given above. They had to click on the voice navigate button to start the navigation. We decided not to check the obstacle detection at the same time as the navigation as we wanted to focus only on the comparison of the systems.

As the navigation started, the participants had to follow the route and reach the destination. They were continuously asked various questions about the system and what they liked and did not like. For the Google maps, the users had to follow the directions as it is, while for Navigator, the users had the option to click the voice navigate button as they pleased to hear the prior instruction.

During the study we noted multiple things like the number of errors they made while following instructions in either cases, number of helping events (for e.g.: in Navigator, the number of times they clicked the “Voice navigate” button to hear the previous instruction), and the number of times they incorrectly clicked a button. These three were the most important characteristics to study as they would help us analyze the perception of the users for both the systems. Also, these three factors were found to help find the biggest differences in Google maps and Navigator. Besides the already defined factors, the time taken to complete each task was also calculated. This variable could be used to judge how comfortable the users were with each app.

Once the route was completed, they were asked to complete a survey to help us better understand how to better the system. . Like in the previous study, they could complete the navigation using a guide dog or cane, once the study was completed to meet our requirements; they were given the required compensation for their time.

The main regions were broken down to 4 parts where we got our participants:

1. Champaign, IL
2. Chicago, IL
3. Orland Park, IL
4. St. Louis, MO

The routes decided for each region with the waypoints are shown below:

1. Champaign, IL routes

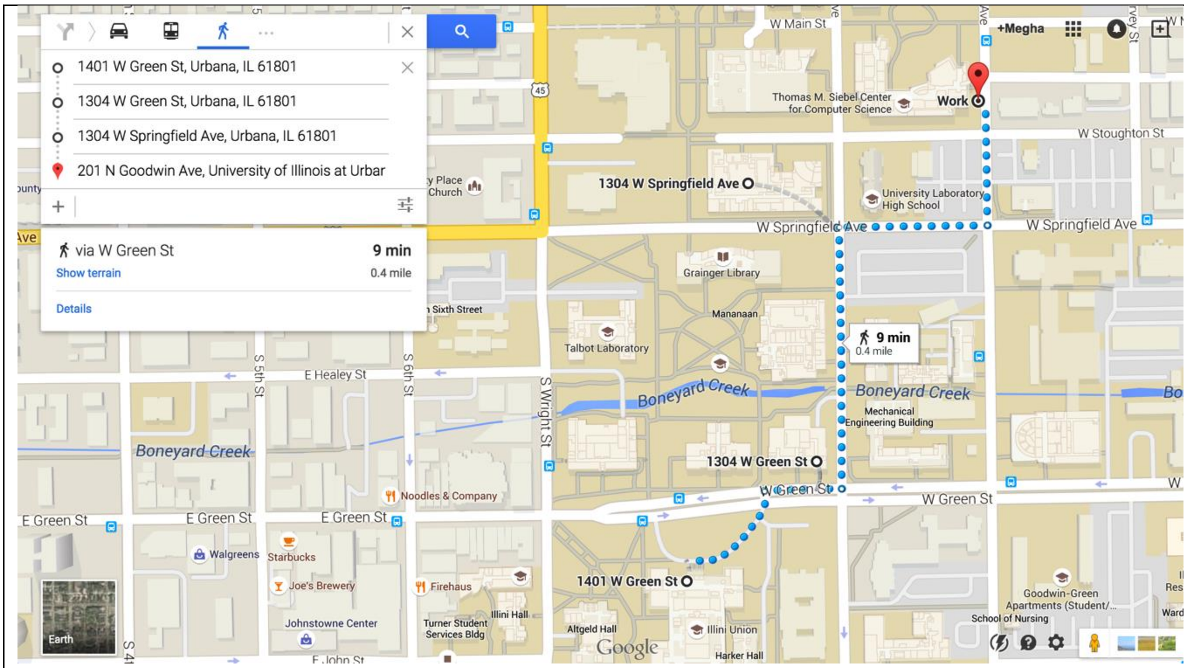


Fig 6.5: Champaign path 1

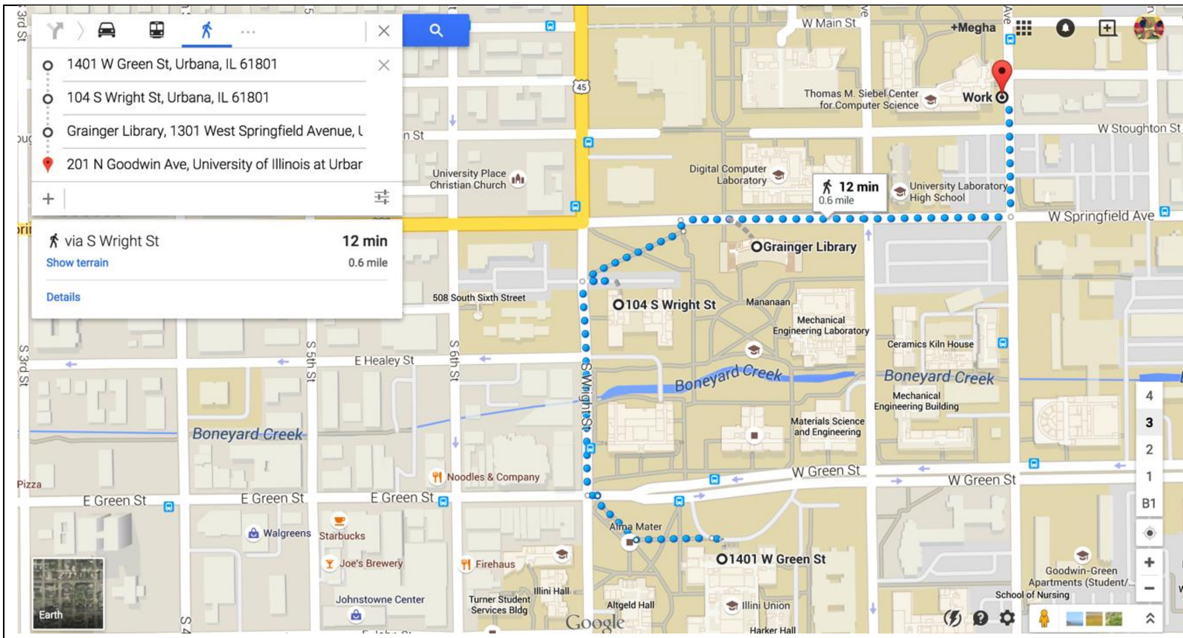


Fig 6.6: Champaign path 2

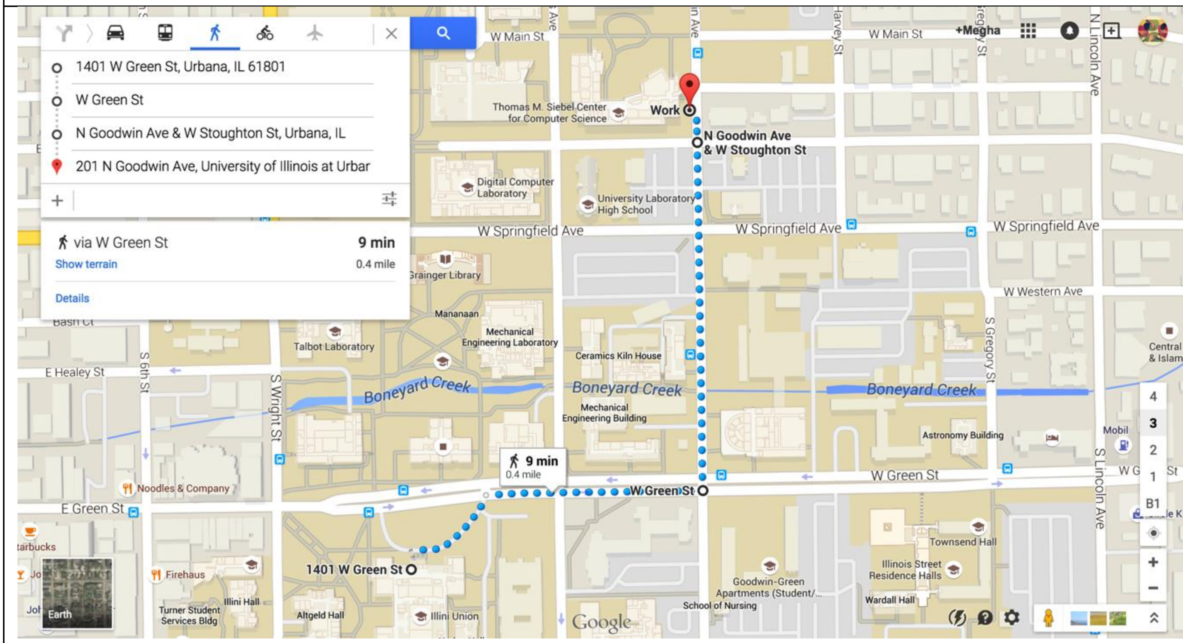


Fig 6.7: Champaign path 3

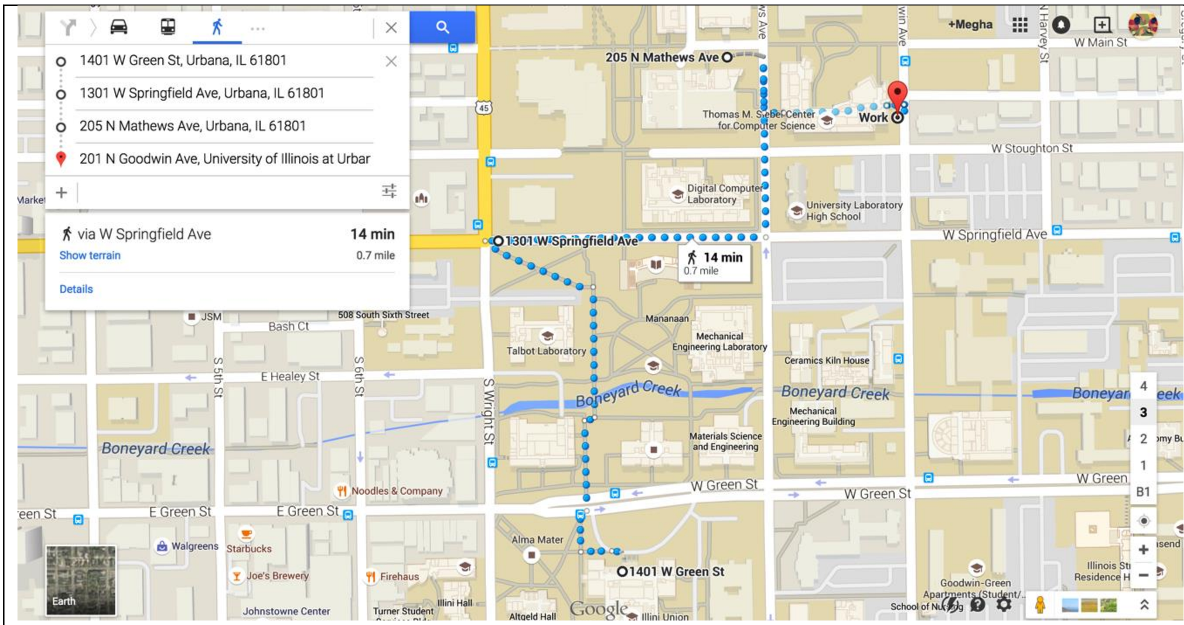


Fig 6.8: Champaign path 4

2. Chicago, IL routes

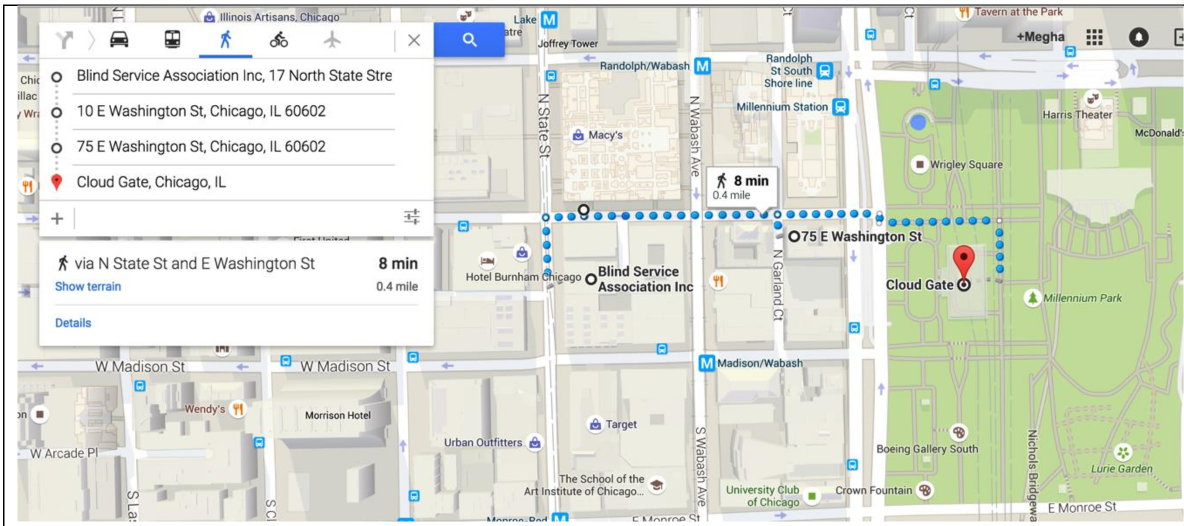


Fig 6.9: Chicago path 1

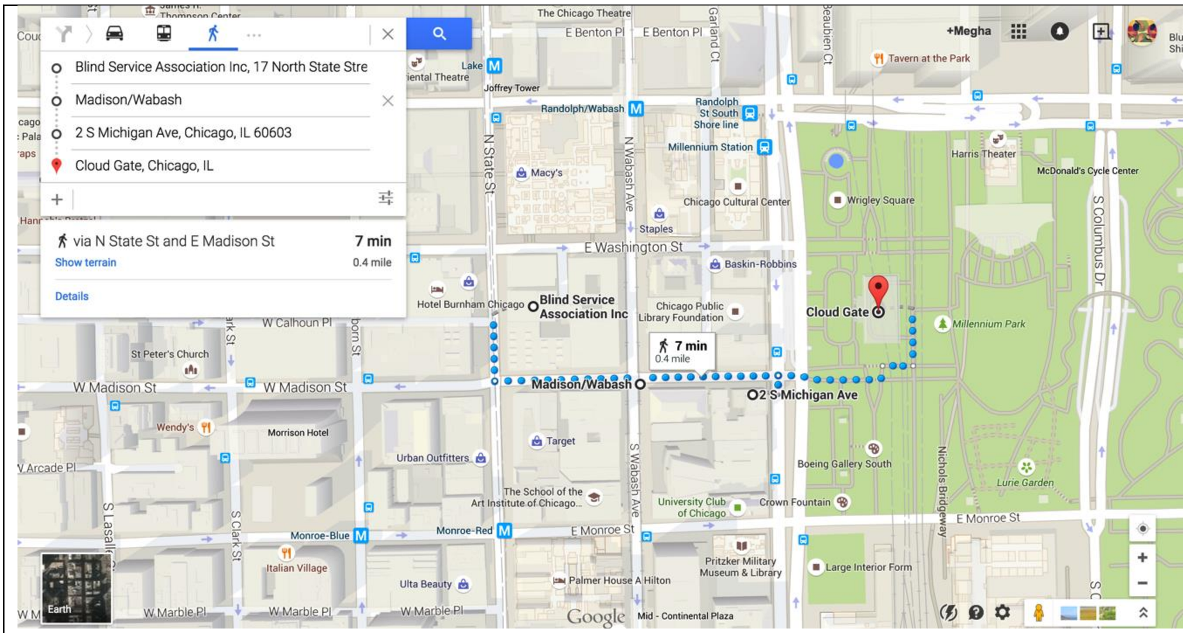


Fig 6.10: Chicago path 2

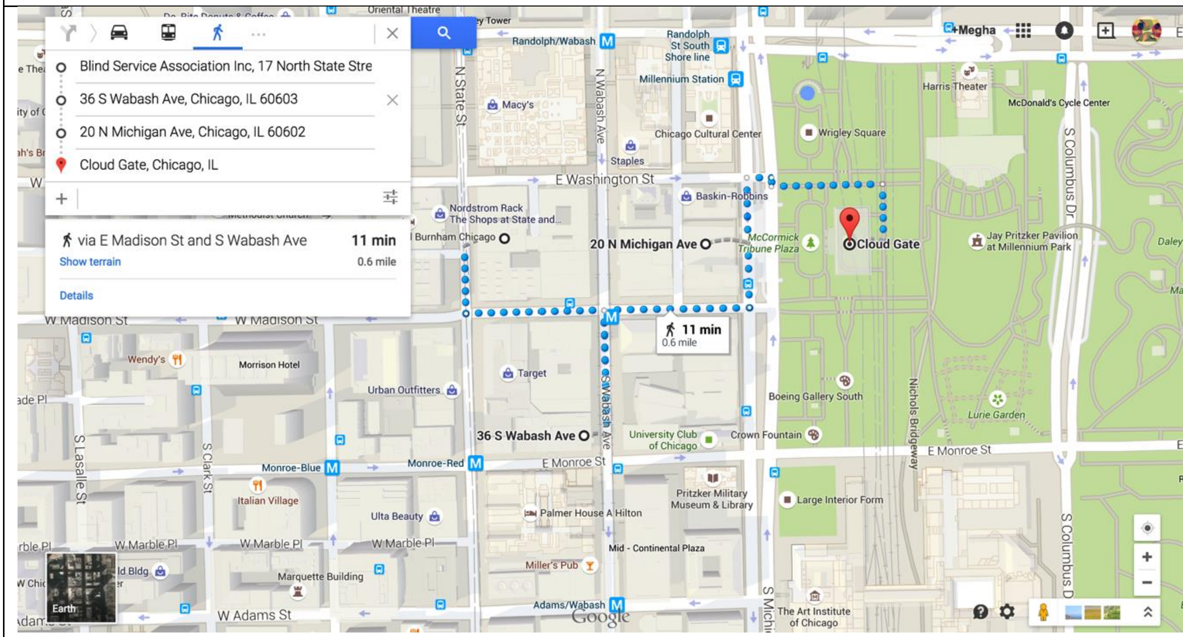


Fig 6.11: Chicago path 3

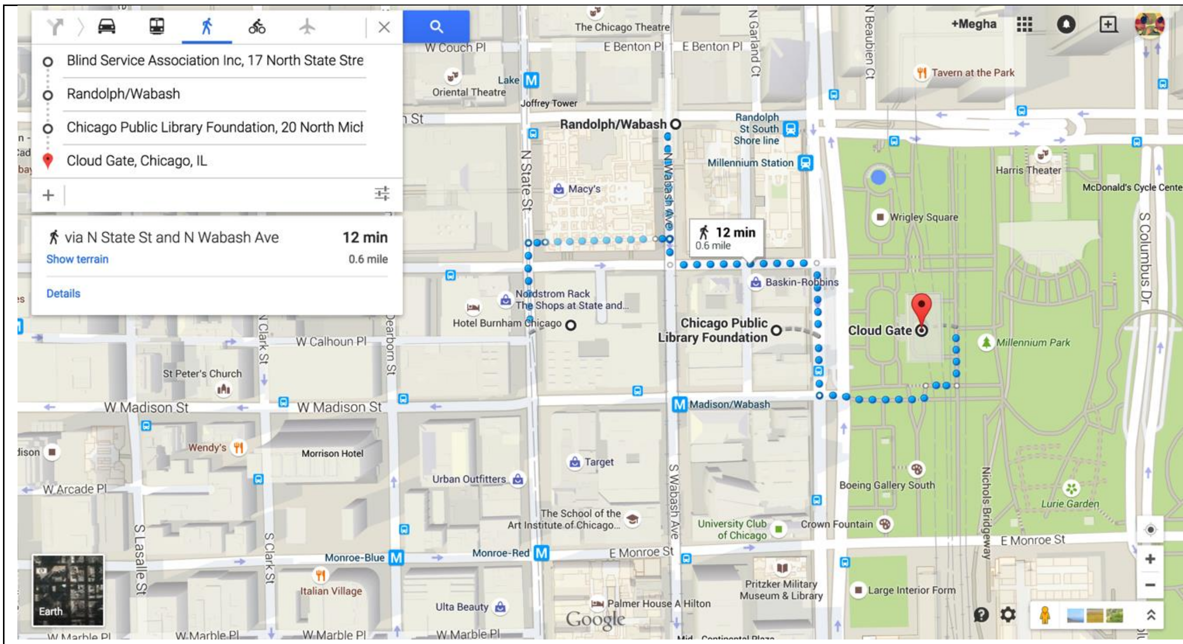


Fig 6.12: Chicago path 4

3. St. Louis, MO routes

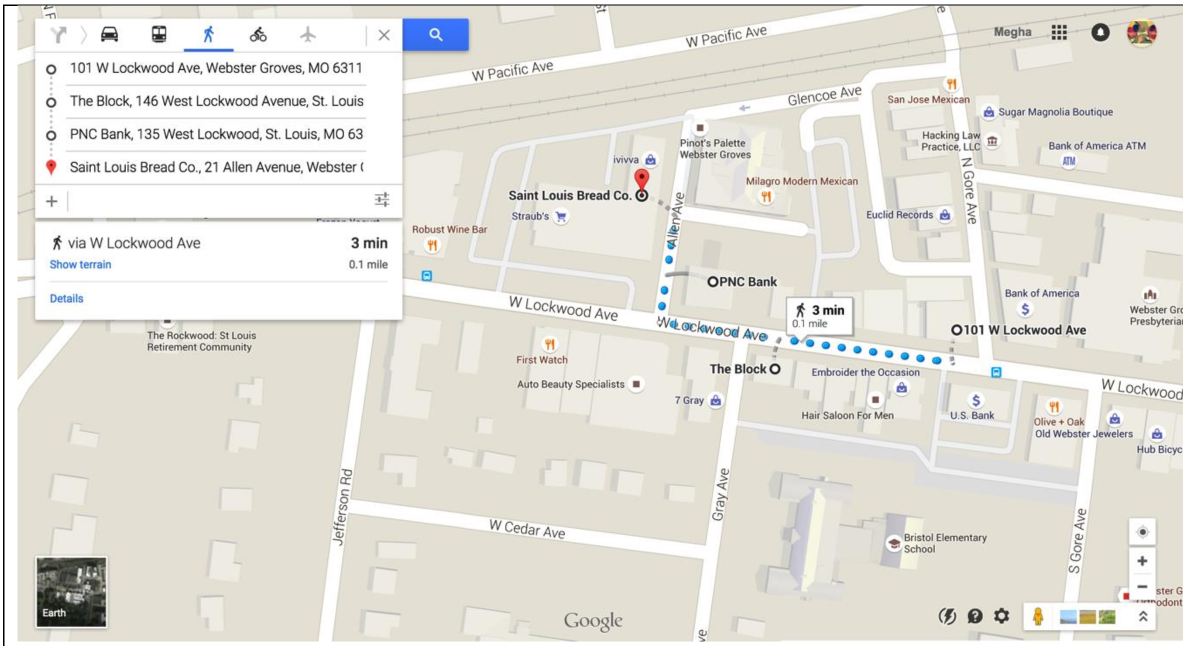


Fig 6.13: St. Louis path 1

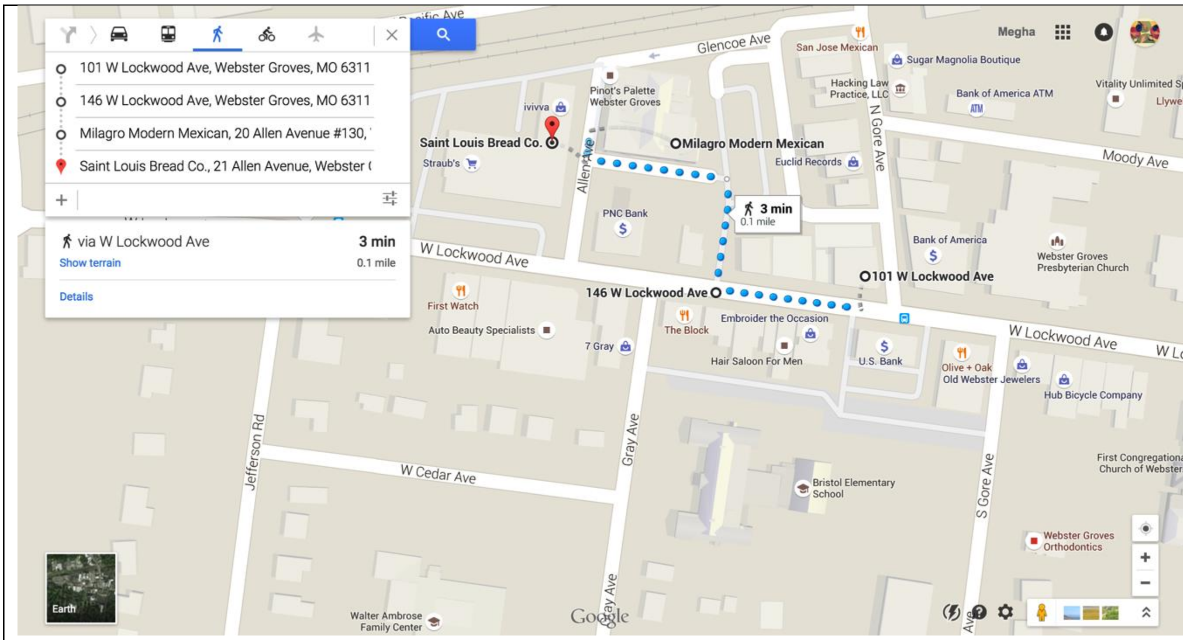


Fig 6.14: St. Louis path 2

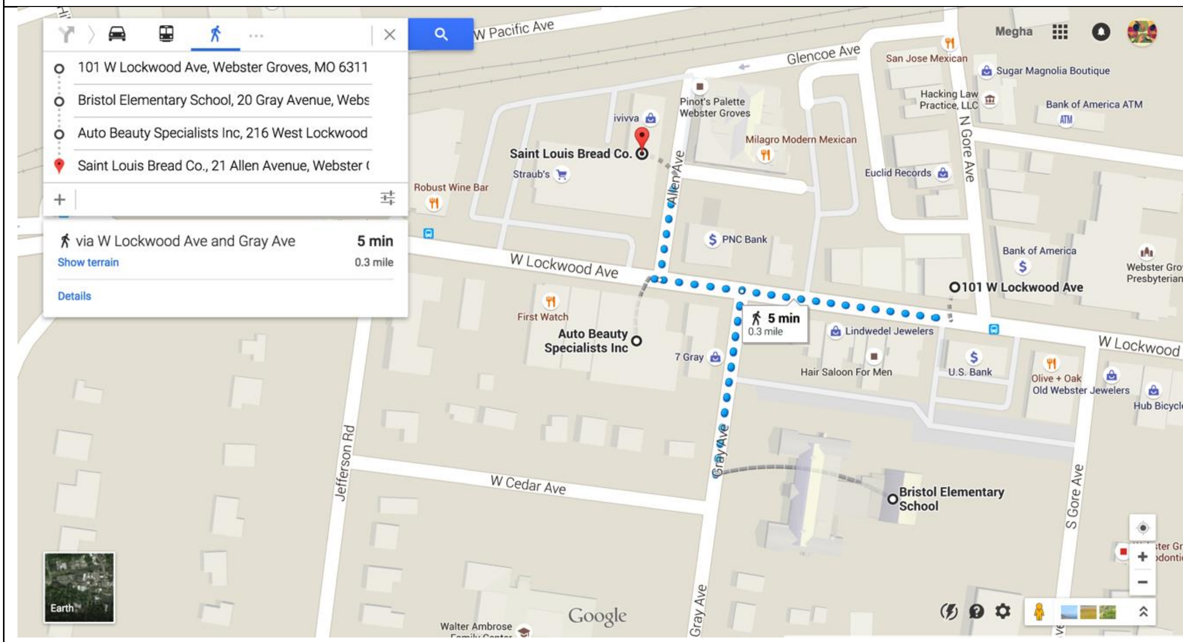


Fig 6.15: St. Louis path 3

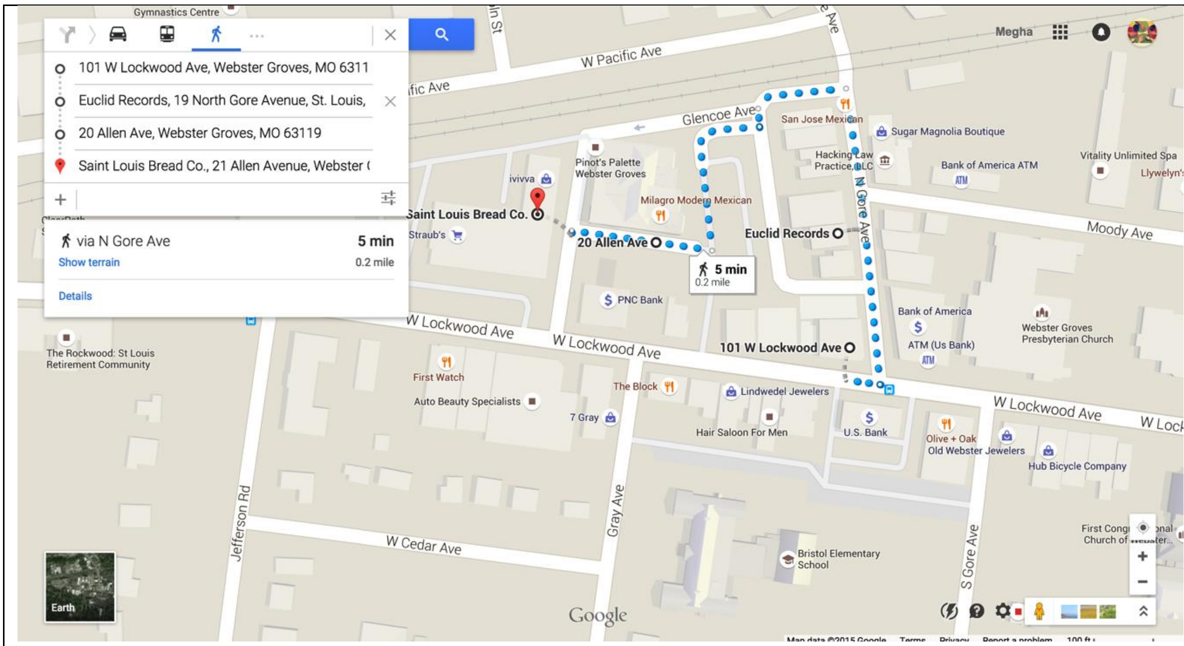


Fig 6.16: St. Louis path 4

4. Orland Park, IL routes

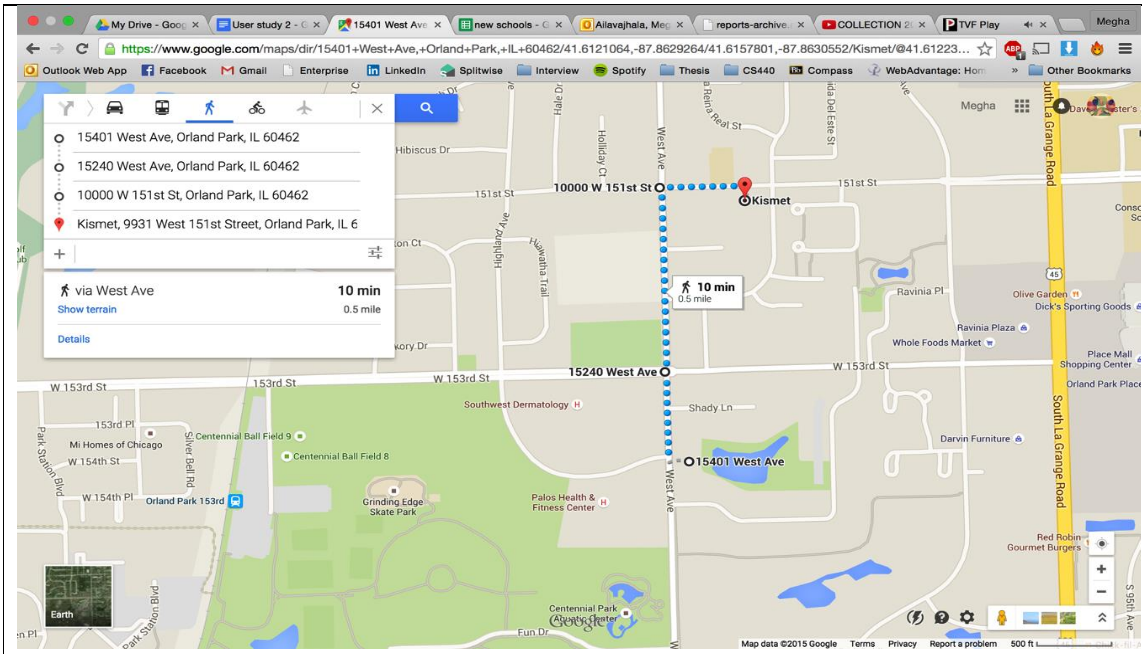


Fig 6.17: Orland Park path 1

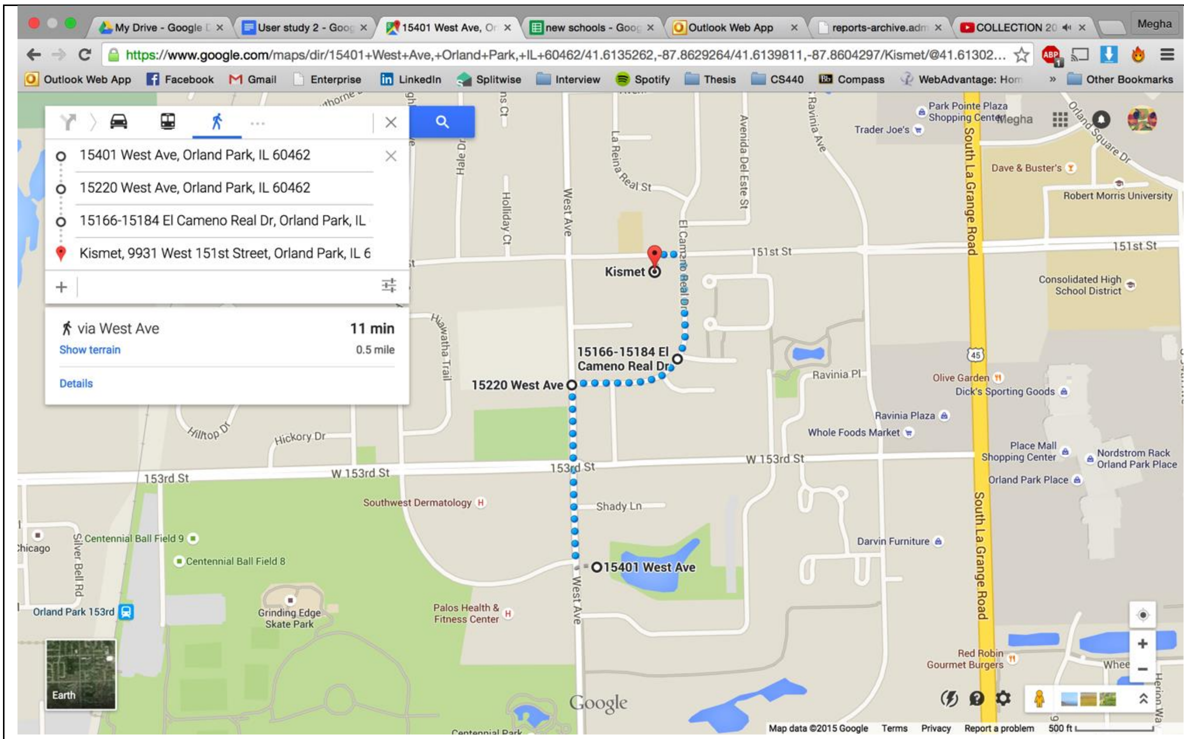


Fig 6.18: Orland Park path 2

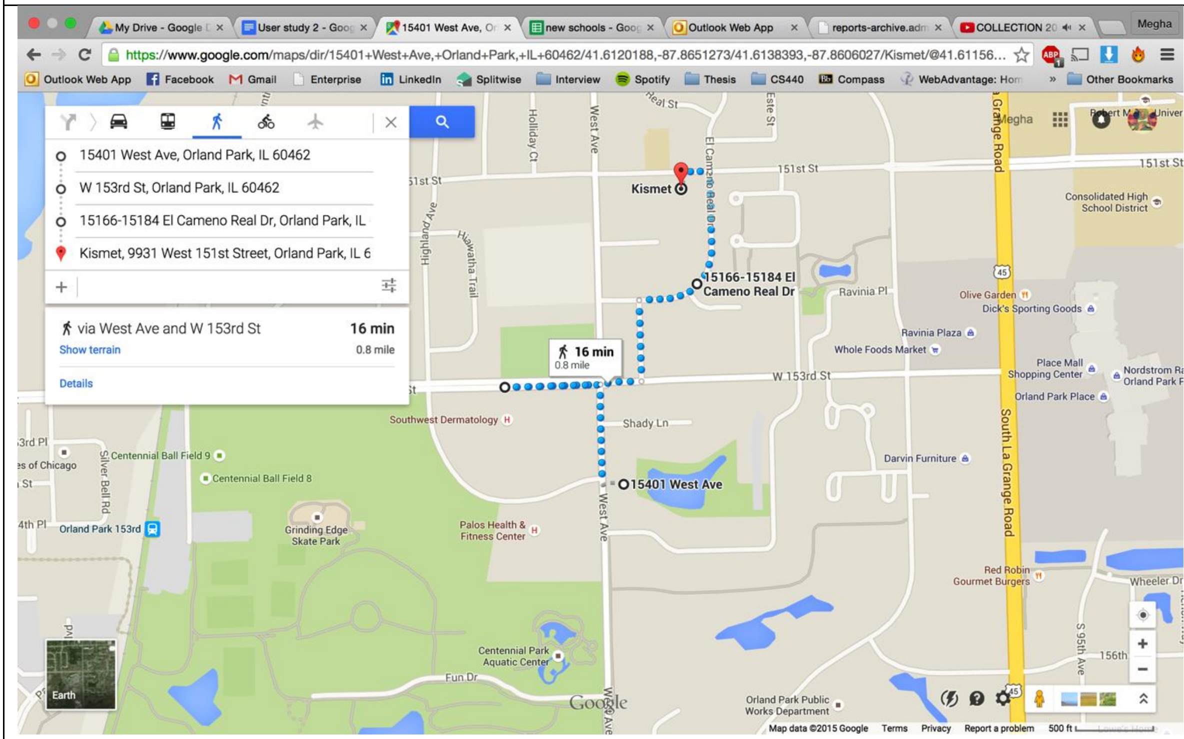


Fig 619: Orland Park path 3

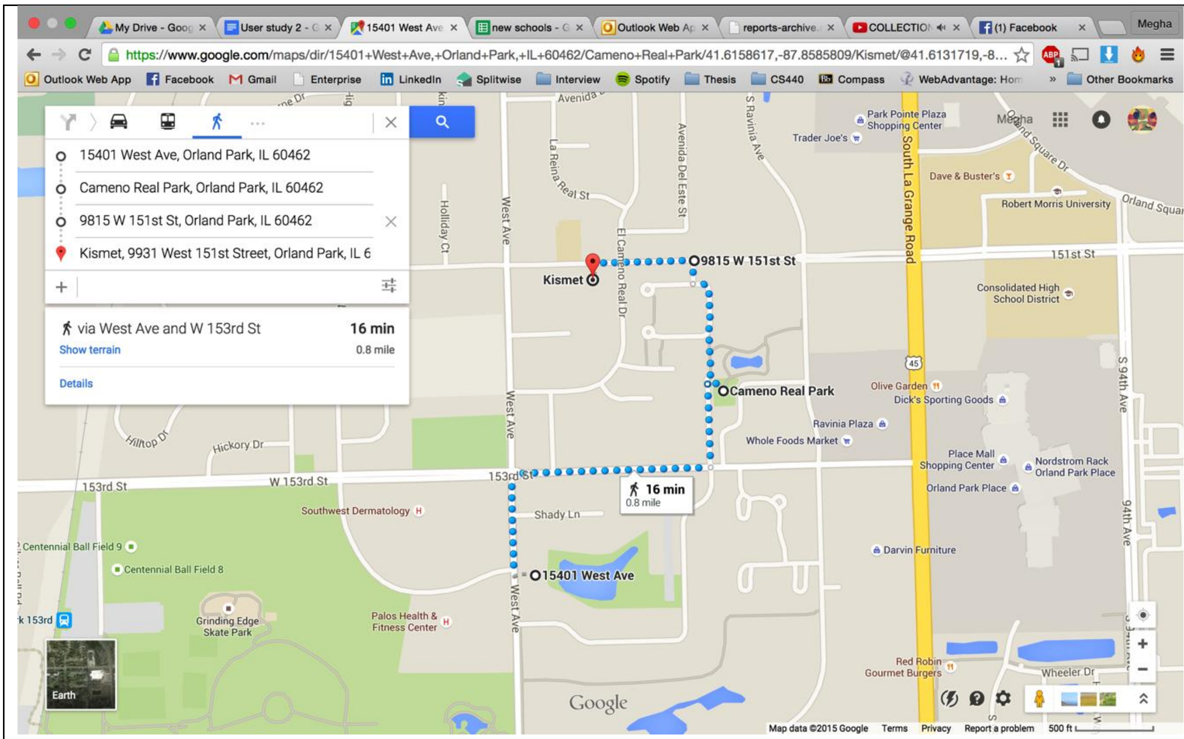


Fig 6.20: Orland Park path 4

6.3 Results

6.3.1 Anova tests

6.3.1.1 Anova for helping events with set and navigation system as independent variables

	df	Sum Sq.	Mean Sq.	F value	Pr (>F)
Set	1	12.04	12.04	1.966	0.176
Navigation System	1	155.04	155.04	25.313	6.4e-05
Set and Navigation system	1	9.38	9.38	1.531	0.230
Residuals	20	122.50	6.12		

Table 6.1 Anova for helping events with set and navigation system as independent variables

We calculated the ANOVA test for the number of helping events by taking both the sets and the navigation system as the independent variable. The point of this test was to see which factor impacted the most to increase the number of times the helping events occurred. The helping events in this case were the number of times the repeat button was clicked as it helped them understand their location.

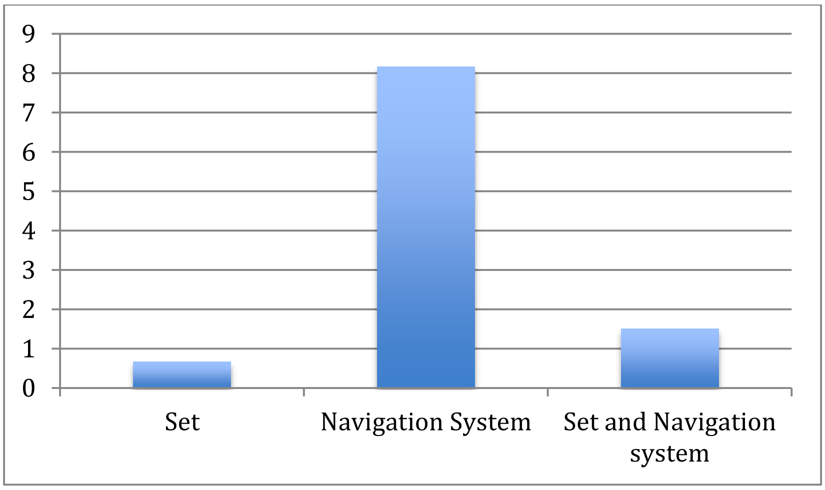


Fig 6.21: Figure showing the ANOVA details for helping events with both sets and navigation system as independent variables

With the test done, we can see that the navigation system chosen has a direct impact on the number of helping events. Statistically we can prove that the navigation system chosen, Google map or Navigator has a significant impact on the number of times the helping event occurred. This makes sense as there was a repeat option available n Navigator and the users felt comfortable to click it to know the previous instruction. Since there is no repeat button in Google Map the participants realized this and did not try and search for any button. Since the button was present in the system irrespective of the set they chose, the set did not have a significant impact on the helping events.

6.3.1.2 Anova for number of incorrect button clicks with set and navigation system as independent variables

	Df	Sum Sq.	Mean Sq.	F value	Pr (>F)
Set	1	0.375	0.375	0.517	0.4803
Navigation System	1	5.042	5.04	6.954	0.0158
Set and Navigation system	1	1.042	1.042	1.437	0.2447
Residuals	20	14.5	0.725		

Table 6.2 Anova for incorrect button click with set and navigation system as independent variables

This Anova test was similar to the one taken above. The impact of the set and navigation system chosen on the number of incorrect button clicks would give us an understanding of how simple the interface was designed for the use of the participants. The more the number of incorrect button clicks, the more complicated is the interface for the users.

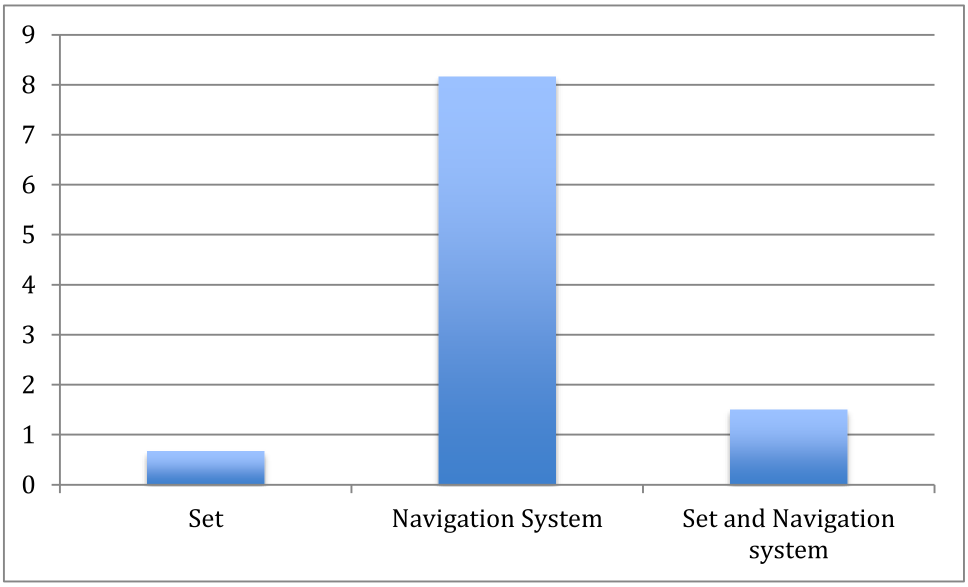


Fig 6.22: Figure showing the ANOVA details for number of incorrect button clicks with both sets and navigation system as independent variables

As seen on the above table we can prove, again, that only the choice of navigation system has some significant impact in the number of button clicks made. Whether the Navigator or Google Map is chosen, the number of button clicks increases and in turn the probability of incorrect button clicks also increases. For Google Map, since the interface has a map to navigate and small button, which require precise clicks, it is quite complicated to use it and one can keep clicking on unnecessary buttons. As the person cannot see, it is important that they are given a more generic idea of where the buttons will be located instead of being precise. In case of Navigator, since there is a repeat button, the user might try to click on it to hear the previous instruction and in turn incorrectly select other buttons.

6.3.1.3 Anova for number of incorrect turns taken with set and navigation system as independent variables

	Df	Sum Sq.	Mean Sq.	F value	Pr (>F)
Set	1	0.67	0.667	0.305	0.5867
Navigation System	1	8.17	8.167	3.740	0.0674
Set and Navigation system	1	1.50	1.500	0.687	0.4170
Residuals	20	43.67	2.183		

Table 6.3 Anova for incorrect turns taken with set and navigation system as independent variables

Number of incorrect turns taken was also another factor by which we wanted to check which system was better: Navigator or Google Map. This test could tell us which had significantly more impact on this factor: the specific path taken by the participant or the system chosen.

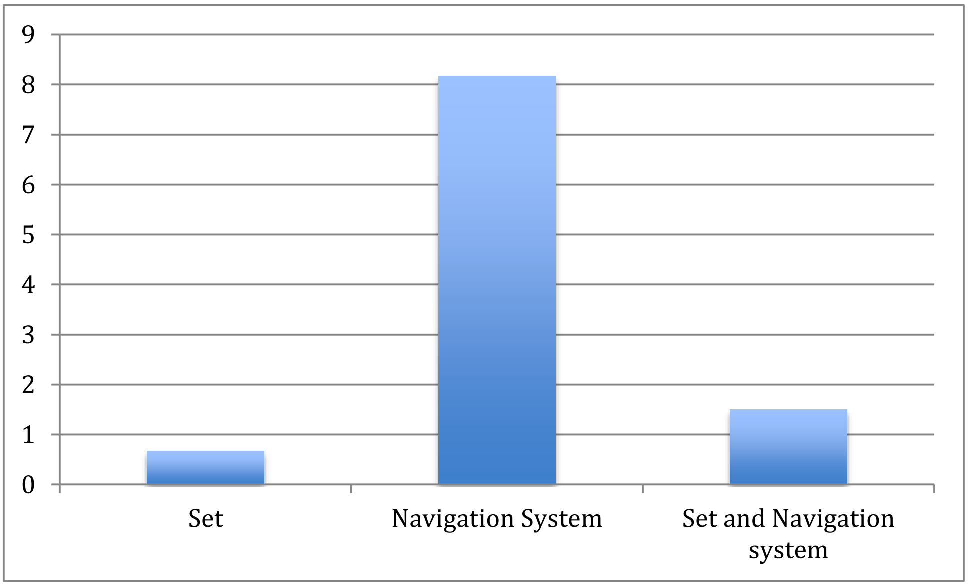


Fig 6.23: Figure showing the ANOVA details for number of incorrect turns taken with both sets and navigation system as independent variables

As shown in the table, the number of turns taken was not dependent on either heuristic. The incorrect turns taken were random in nature and it was difficult for us to analyze what caused this. We assume it was because of the spatial understanding of each participant was different and how they updated the environment was unique. This test can also help us proves that each users perception of the instruction was different and one could not base it on a standard environmental or any other factor.

6.3.1.4 Correlation between the helping events and the incorrect button clicks

After testing for the correlation and the impact of the helping events and the incorrect button clicks, we found the following result:

t = 2.9646, df = 22, p-value = 0.003579

As seen, the p value is significantly less than 0.05, which proves that the number of helping events and the number of incorrect button clicks have a linear relationship. Statistically we can see that as one variable increases the other increases too. The true correlation is greater than zero in this case.

This proves that as the a participant was clicking incorrectly while actually trying to click the "Voice Navigate" button, there was a significant increase in the number of times he was actually clicking the "voice navigate button". One can see this clearly when a person who incorrectly tries to click on the "Voice Navigate" button would click the actual button a significant number of times.

6.3.1.5 Correlation between the helping events and the incorrect turns taken

The results of the correlation tests are as follows:

t = 2.0796, df = 22, p-value = 0.02471

In this case too, the p-value is less than zero and we can claim that the true correlation is greater than zero. The alternative hypothesis in this case is that the number of helping events is positively associated with the number of incorrect turns made.

We can also prove by this test that as a person clicks on the "Voice Navigate" button to know the next instruction, the number of incorrect turns made would also increase linearly. One such case can be as the person keeps taking incorrect turns, he would like to know more about the next instruction and would keep clicking the "Voice Navigate" button to know more.

6.3.1.6 Correlation between the incorrect turns taken and the incorrect button clicks

We conducted another correlation test to understand the impact of the number of incorrect turns made and the number of incorrect button clicks. The result is as follows:

$t = 1.0727$, $df = 22$, p-value = 0.1475

In this case, the p-value is higher than 0.05 but it is greater than zero and we can say that the alternative hypothesis is true here. The hypothesis would be that the number of incorrect button clicked linearly and positively influences the number of incorrect turns made. This implies that a person would have a significant impact in the number of incorrect button clicked based on the incorrect turns taken. This can be attributed to the fact that he might get distracted if he misses a turn or take a wrong turn and incorrectly presses the "Voice Navigate" button.

6.3.1.7 Correlation between all three features- the helping events, incorrect turns taken and the incorrect button clicks

This test was done to see the correlation between multiple variables, viz., the number of helping events, the number of incorrect button clicks and the number of incorrect turns made.

The results achieved are as follows:

	Number of helping events	Number of incorrect Button clicks	Number of incorrect turns
Number of helping events	1.00	0.53	0.41
Number of incorrect button clicks	0.53	1.00	0.22
Number of incorrect turns	0.41	0.22	1.00

Table 6.4 Correlation between helping events, incorrect turns taken and the incorrect button clicks

As we can see from the data above since the p-values are all greater than zero we can assume that the alternative hypothesis is true. In this case the alternative hypothesis would be that the number of helping events has a positive impact on the number of incorrect button clicks and the number of incorrect turns.
We can prove this by considering that as the participants uses the system and clicks incorrectly on the "Voice Navigate" button to know the next instruction, the person would also linearly increase the chances of clicking on the actual button or take incorrect turn based on the instruction.

This can also be true about Google Map. As there is no repeat button available, the number of incorrect turns will decrease with time as they get used to the system. There would also be a decrease linearly in time on the number of incorrectly clicking any button.

6.3.1.8 Ratio between the number of incorrect button clicks and total number of clicks

		Set 1	Set 2	Navigator	Google Map
Total incorrect button clicks		14	17	21	10
Total number of helping events		39	56	78	17
Ratio		0.264	0.233	0.212	0.370

Table 6.5 Ratio between the numbers of incorrect button clicks and total number of clicks

This table tells us about the ratio between the numbers of incorrect button clicks and the total clicks in both the sets and both the systems. We can see by the ratio that the number of incorrect button clicks for set 2 decreased than that with set 1. We can conclusively say that as people learnt about the system they were able to reduce the number of incorrect clicks made. For the comparison between Navigator and the Google Map, the ratio being higher for Google Map, we can assume would be when people are unaware of the interface of Google Map. The people who used Navigator before Google Map and were unaware of the system would assume that there would be a repeat instruction button in Google Map too and would make incorrect clicks.

The tables of means were also calculated [Appendix D].

6.3.1.9 Planned route vs. actual route

1. Number of turns taken

	Number of turns taken	
	Planned route	Actual route
Mean	4	4.8
Standard Deviation	1.15	1.55
95% CI	0.72	0.96

Table 6.6 Results showing difference in number of turns taken in planned route vs. actual route

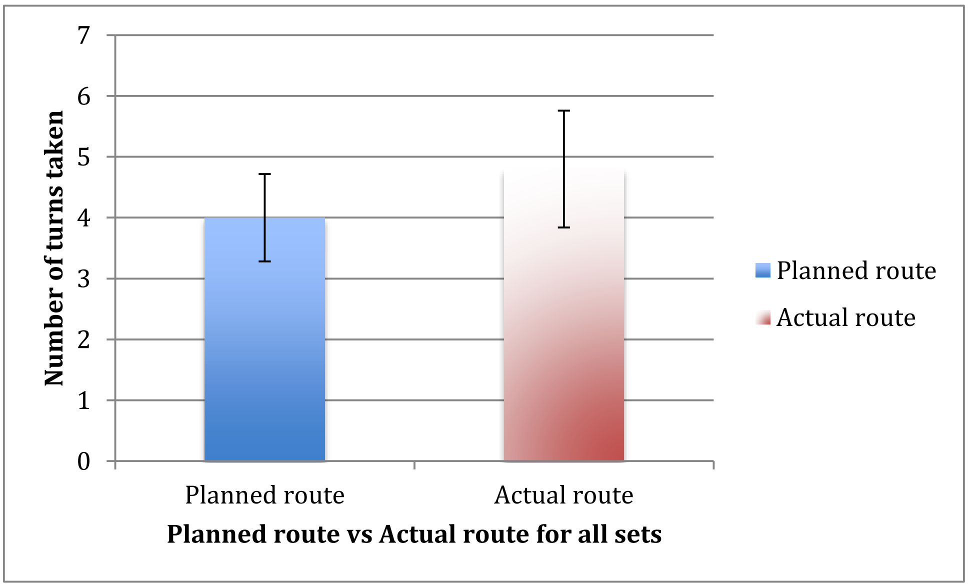


Fig 6.24: Comparison in the number of turns taken between planned route and the actual route

The idea of comparing how people perceived a route and the route that was actually taken would give us a better understanding in the difference of the rotes and where they were different. This figure compares the number of turns that a participant would make in the planned route and the actual route.

The p value of this difference is 0.208, which conventionally speaking is not statistically significant. This proves that even though the participants planned a route that would use shortcuts, the number of turns are almost similar and do not prove to be a big problem. We also noticed that the due to the statistical insignificance in the number of turns, the actual route might be equivalent to the planned route.

2. Time taken in min

	Time taken (min)	
	Planned route	Actual route
Mean	10.9	9.8
Standard Deviation	4.63	1.55
95% CI	2.87	0.96

Table 6.7 Results showing time taken in planned route vs. actual route

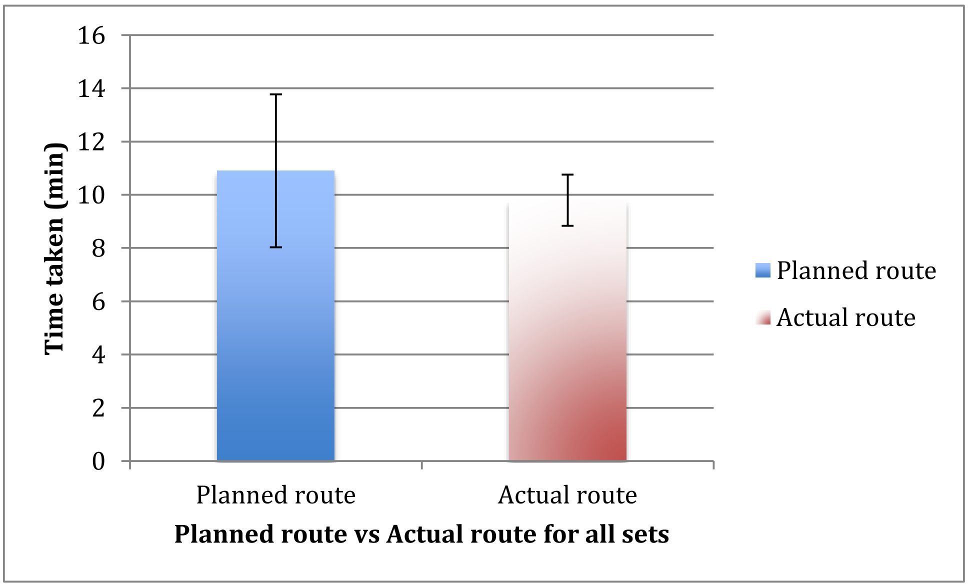


Fig 6.25: Comparison between the planned route and the actual route in terms of the time taken to complete the route.

Considering the time taken to travel a route would give an idea of how people plan their route and whether the travel time is important or not.

By looking at the graph we can see that for all the sets, the planned route by the participants usually takes more time. This might happen because even though people might now the short cuts to avoid the freeways or traffic, it might still take more time. The p value for the difference is 0.491, which is statistically not significant. We can thus prove that scientifically the time taken to travel a route be it planned or the actual one does not have a major difference.

3. Distance travelled in miles

	Distance travelled (miles)	
	Planned route	Actual route
Mean	0.5	0.52
Standard Deviation	0.23	0.10
95% CI	0.14	0.06

Table 6.8 Results showing difference in the distance travelled between planned routes vs. actual route

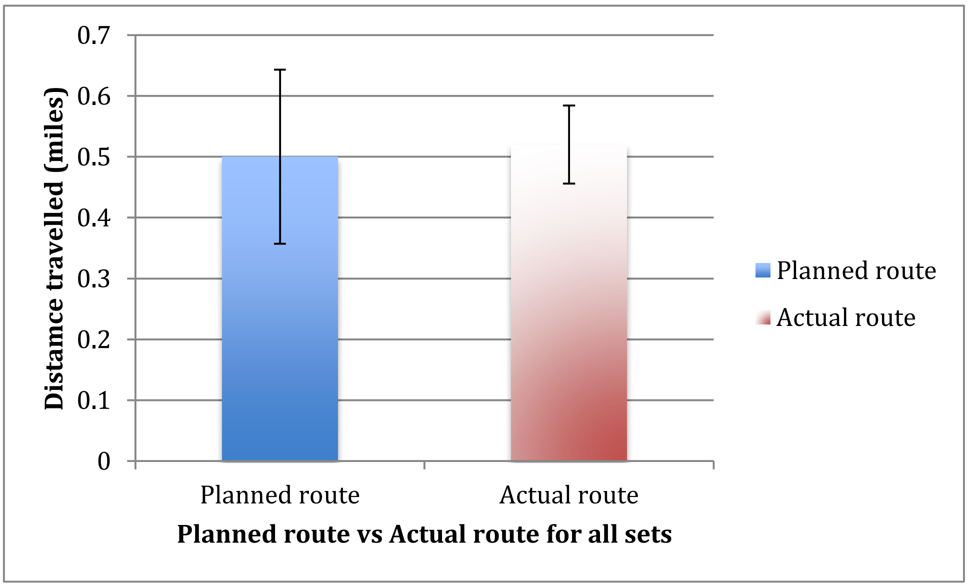


Fig 6.26: Comparison between the planned route and the actual route for all sets in terms of the distance travelled.

The distance travelled in each route might be different for the sets but we tried to get a more general idea on all sets and all points to understand the difference.

The p value for the planned route vs. actual route in terms of the distance travelled is 0.807. This implies that conventionally speaking, the difference is not statistically significant. We can see by the graph that the difference in the distance is not a lot in terms of the planned route and the actual route taken. One reason can be that the participants might now the routes to avoid the major traffic but it might not be a shortcut and be equivalent to the actual route itself.

With the different measurement of comparing the planned route and the actual route, we can see that statistically speaking, there is not much difference in the planned route and the actual route taken for the sets described in the task. This also helped us in realizing that the participants might have known the shorter routes or other shortcuts that the GPS might not know, scientifically speaking there was no difference in the planned route and the actual walked route taken.

6.4 Summary of results

There were a number of tests done to figure out which navigation system is better to be used based on various factors such as the number of helping events, number of incorrect button clicks and number of incorrect turns taken. With these tests, we can scientifically prove which system is better to use and fulfills all the requirements of the visually impaired.

Based on number of helping events (number of times the repeat button was clicked, we calculated the p-value as 0.036 for Set 1 and 0.0050 for set 2. Even though the participants were given different location for each set based on their location, since overall the distance and time was almost similar, we decided to conduct the test on the sets as one. Based on the tests, we found that with time, people got more and more aware about the functionalities of the buttons in each system. With Google map we found that people realized soon that there was no repeat button and it would automatically give the instruction once there was a turn. However, in the navigator, the users had the option to click the “Voice navigate” button to repeat the previous instruction and they had to continuously click it to know when to turn.

Based on the number of incorrect button clicks, p-value calculated was 0.0593 for set 1 and 0.3197 for set 2. We can see that the number of erroneous button clicks significantly decreased in set 2 for Navigator and Google Map. As already explained, with time, the users got more and more familiar with the interface and knew where to click on the screen. Also, with Google Map, the users started realizing that they could not click anywhere to repeat the previous instruction.

Based on the number of incorrect turns taken the p-value was 1.00 for set 1 and 0.15 for set 2. This was an interesting test and was also able to prove how Navigator, our design system was better than Google Maps. The number of turns made for each set in both Navigator and Google Maps were not significant to be noted. The number of incorrect turns taken was very random and not dependent on any system or set of points used.

The planned route vs. actual route difference would tell us how any navigation system and a person's cognitive intelligence decided routes based on origin and destination location. For planned vs. actual route the p-value was 0.208. Since the value is greater than 0.05, we cannot significantly rove which route was better and whether the system had any impact on it.

We also decided to compare how different the planned route was with actual route to analyze the difference in detail and understand how we can change it for the better. The test revealed that there was no significant difference even with the some users knowing shortcuts to reach a destination from the origin.

- Time taken: p-value= 0.491

The time taken to complete the planned route and the actual route was also not significantly different to note, one can attribute this to the fact that either Navigator or Google map would give a route that would be almost similar to the planned route.

- Distance covered: p-value=0.807

The total distance covered for the planned and actual route was also almost similar. The reason can be the same as for the time taken to complete the task.

We also calculated the Anova tests for Comparing Navigator and Google maps

- Based on the number of helping events: ch-value= 0.000391

There was a significant different in the number of times that the helping event occurred in Navigator than in Google map. However, this was understandable and expected as there was a repeat button given in Navigator that could be used to hear the previous instruction, while there was no such button given in Google Map.

- Based on the number of incorrect button clicks: ch-value= 0.056

There was no serious difference in the number of incorrect button clicks in wither case. We can see that with time as people started getting used to the interface, the number of incorrect clicks would automatically reduce.

- Based on the number of incorrect turns made: ch-value= 0.2261

This was an interesting result that we observed. Contrary to our belief there was not a significant difference in the number of turns that were made by using either system. We guess as the users started using the system they became more aware of how and what the instruction meant and how to follow it.

- Correlation between helping events and the incorrect button clicks: ch-value= 0.0036

We found there was a linear relationship between the number of helping events and the number of incorrect button clicks. As expected, this was quite obvious. As the number of incorrect button clicks increases, the probability of clicking the actual button also increases.

- Correlation between helping events and incorrect turns: ch-value= 0.0247

There was a positive association between the number of helping events and the number of incorrect turns made. As the number of clicking (or in the case of Google Map, not clicking) increased, the probability of one missing that instruction and taking an incorrect turn also increases.

- Correlation between incorrect turns and incorrect button click: ch-value= 0.1475

The hypothesis was that the number of incorrect button click would linearly increase the number of incorrect turns made as the user might get confused and miss a turn when they incorrectly clicked a button. The test revealed that our hypothesis was true.

- Correlation between all the three variables

This test was probably the most important as it gave us accurate comparison of how our design system Navigator did with Google Map. The ch-values were between 0.22 and 1.00

and we saw that with the increase in button and helping events the number of incorrect turns and incorrect button clicks might also increase.

With all these tests, we could significantly prove that though there are some features in Navigator that can be improved, most of the features are working well with the suggest crowd of visually impaired people. People who are already using existing apps like Google Maps also felt with time, they were able to use Navigator much more comfortable and easily. As with any product, this product also has a learning curve and once they were able to understand the functionalities, they were able to do almost all tasks easily and comfortably.

With the feedback we received from the users, the biggest difference in the first and second study was the size of the buttons and absence of the maps. This was a welcome change that all the 12 participants liked as even people who could see the screen had a tough time seeing the map in the previous study. It was also interesting to note how people who have never used a navigation system easily adapted to both, Navigator and Google Map.

As the participants used the Navigator to actually walk on a specified route, there were cases when some of them did not know the routes very well. It was interesting to note the number of times the repeat button in Navigator was clicked was independent of whether the participant knew the area or not. This was completely unexpected as we thought that the user familiar with the area would not use the navigation system as much as the one who did not know the place well.

CHAPTER 7

SUMMARY OF ALL RESULTS

At the start of the research we had many questions in mind about developing an android navigation system that could help visually impaired people travel independently and safely. The study were designed to help us solve these questions so that we could develop an app that could not only relive the stress that is caused to this community while traveling alone but could also be cost effective and time efficient.

Our first research question targeted at the demographic characteristics of the people and we wanted to see how that would affect the way they use the system. We found that only the blindness level was affecting their control of the system and the device. Gender has little to no influence on the way the navigation system was used. However, we found that women easily understood the system and did not take a lot of time trying to get used to the system, while men made more error while trying to use the system.

We also tied to calculate the time taken to complete the tasks and found that the average time to complete the task in Navigator was 9.7 s for men and 13.8 s for women. For the case of Google Map interface, the time taken was 16.4s and 22.2s for men and women respectively. This gives rise to the question that even though women made fewer errors they took a considerably longer time to complete tasks. A basic question of cognitive and perceptive intelligence can be answered by this study. Women might take longer time to complete a task because they are mentally mapping the interface and thinking of where to click while men like to map as they use. This was a very interesting observation that we got from the user studies.

Another interesting observation from the study was the presence of helping devices while doing these tasks. All the participants were given the option of keeping the cane or guide dog and we found that it did not matter which helping device was used; the tasks were done the same way. Since the dog is trained to only walk when the owner requires it too, he was not a distraction to the user.

The interface design was very crucial. We had already discovered that it was important to have a system that can be used globally among all the members of the community with the same ease. As expected the interface with bigger buttons did extremely well than the interface that had smaller buttons and a map. Bigger buttons meant, the probably of error while clicking on the button decreased considerably. The tests that were done in the first user study confirmed our point.

Since the study was conducted in a common location that was known to the people, some participants were also familiar with the routes we chose for the studies. This could pose as a big problem and we wanted to see if people who were familiar with the area would respond differently to the people who had no clue about the routes. While comparing the actual route that was taken and the route the participants would have taken to go from the origin to the destination, it was quite interesting to find that the time taken and the distance covered would have been almost the same. We were also curious to see how this factor would affect other heuristic. It was quite unusual to see that the number of incorrect turns taken were not dependent on this factor as people mostly wanted to follow the system even if it was wrong.

Not only did we have people who were unfamiliar with the environment we also had people who had never used a navigation system before. Some people were used to being helped while they travel, by either being dropped off to their destination of choice or by having a companion. We were very curious to see how such group of persons would react to using a navigation system for the first time. It was very impressive the way they picked up the different features of the system and were able to access it very easily.

For the people who were used to a navigation system, we were very inquisitive to see them compare our system to the ones, which they used. However, it was important to standardize the other app and thus, we chose Google Map. Google Map gave us a wide spectrum of tests to compare Navigator with, as it was something that was very popular and very easy to use. Based on the tests, we found that Navigator performed almost as well as Google maps in most of the tasks. In fact Navigator did better than Google Map as there were features specially designed for the visually impaired while Google Maps targets people who can see the screen.

It was very interesting to find that the unique features that were added to the system based on the first study were appreciated and accepted by the users. These features include the repeat button to hear the last instruction, absence of the map to give space to bigger and larger buttons. Since we had participants who had never used our app (from the first study) and those who had used it, it would be quite fascinating to see how both these groups of people would do the tasks. We were surprised to find that all the tasks done were irrespective of the fact stated earlier.

The object detection part was improved to be less sensitive and able to detect some standard objects like telephone and electricity pole and trashcans. The participants were also impressed with the addition of different musical tones for the height of the object. As the participants played with this aspect of the system they were made aware of this unique feature that would help them deter from any obstacles in their path and avoid collision.

Some of the challenges we weren’t aware of during the development of the app included the loss of mobile data signal, distractions in terms of other people stopping the study and other environmental factors. External factors and distractions were something that we could not avoid though it would’ve definitely be intriguing to see how the participants would react in a controlled environment. However, we did not want to do a study in a much stricter environment as we had designed the application to work in real life situations.

With these studies we were able to realize the solutions to our major research questions that were raised in the research phase. We were also able to inculcate the existing and previous work with the feedback received to design and develop a system that the participants would be happy to use and also recommend to their friend.

CHAPTER 8

FUTURE WORK

With the help of the application developed, we can help a number of visually impaired people in their daily lives and their day-to-day chores. The application would not only help them overcome dependence on others, become financially secure and stable and lead an independent life. The application can, not only help the users navigate from one place to another, it can also help them guide throughout the way by pointing obstacles.

According to the results calculated we can see that the button size were a big problem in the first study and had to be solved in the second study. This is the reason why we decided to go with larger buttons in the second study. Also, since we are targeting the entire blind population, which includes partial and completely blind people, it was important to have the map to be of a decent size. For the second study we tried to completely take out the map but studies showed that people with partial impairment requested the map. We would include the map but make it an option to use and navigate on instead of it being necessarily there.

Another important aspect that needs to be worked on is the speech to text system. Currently the system only targets people who can speak and understand American accent. It would be very important to make the system more global and have an option of changing the option based on the demographic and location. Since it is a very important characteristic of the application as the visually impaired people interact with the app using this system, it is very important to not only better it but make it efficient so that there are repeat options for them to understand the last instruction. However it was found in the studies that people wanted to know the next instruction instead of previous instruction. Currently, the instruction repeats the last step taken but the users would prefer if it updates the distance left to travel. The users also wanted the repetition to be automated and yet, have the option of repeating the instruction. This would give the search a much more user-friendly system where even if they forgot to click the button they would be told the next instruction.

The cane is the most trusted object for the people with visual impairment. Since the users are familiar with the cane, designing the system such that it can be connected to the cane to detect obstacles is also underway. This would also decrease the processing time of the system. Having a Bluetooth technology would also decrease the complexity of involving a camera when there is a lot of foot traffic. The Bluetooth technology can easily be used to detect one person or many in the path of the user. Not only that, it would also be much better in places with less or no light.

The instructions given by Navigator were considered much better than those in Google maps but the instructions could've been much better. The participants felt that the adding more instructions to the current way would give them a much better idea of their environment, for e.g.: instead of "turn left" they could say "turn left at W. Elm Street", etc. Also, more instruction especially at crossings and intersections would also provide them with a much better grasp of their surroundings. The simplest way can be to provide them the distance to the next intersection before taking a turn.

CHAPTER 9

DISCUSSION

Navigation is the process of travelling and controlling movement of a person from one place to another. In the early days, people used to either ask people as they start the travel or plan ahead of time. Later paper maps was used to understand the route and with the increase in the use of technology, everything is now digital. There are multiple devices that can help a person give the exact location and also give turn-by-turn instructions throughout the travel

With the innovation of mobile devices, there was an increase in the development of different navigation applications for then. Each of these app could not only help them give various instructions but could also re-route if a person is lost, give information about their vicinity and so on. However, most of these apps are only helpful for people who could see the screen and actually access it. There were few to none apps for the disabled people to use specially the visually impaired.

There are a few devices that can help the visually impaired navigate by giving instructions at each step. But one has to buy such devices separately besides any other helping aide. These devices are expensive and cannot be used everywhere. Also, very few people are aware of these devices and the unfamiliarity of the products also does not enable the visually impaired to use it more often.

Most of the current systems in mobile devices are not designed to the need of the visually impaired. They do not have enough talk back options to be able to use it without physically touching any section of the phone. Be it Google Maps or Waze (on android devices) or iMap (on apple devices), they are not compatible to the comfort of the visually impaired. Even though the maps on all these devices have zoom able and rotation features, it is still difficult for the partial impaired to use it.

There are devices and apps that can help detect objects and obstacles in one's path but they are also separately sold than the navigation system. This would imply the user has to buy both the apps and see them simultaneously which none of the mobile devices allow as of now.

The idea behind designing and developing an app was to help people with visual impairment lead an easy life. With the problems they already have, navigation can be something that can be solved and made easier on them. It would also help them be more confident and do daily work without any outside help. Having an app in their mobile phone also means fewer devise to carry besides their helping devices like canes and guide dogs.

Though all the user study for our app were done in US, it was also important to keep in mind other parts of the world where people were not as fortunate as here. There are parts of the world where the basic facilities are not provided for the visually impaired and we had to take them into consideration and their needs too. For e.g.: based on our research we found that many people in India cannot afford an iPhone, so designing an app in android operating system would make more sense. We also felt that using miles would be unfair as it is used only in some parts of the world while other parts of the world used a metric system to discuss the distance travelled.

We have tried to design a system that can be used on a more global platform by any and all visually impaired people. Not only did we try to concentrate on the completely visually impaired people, we also looked into the needs of those who are partially impaired. It is important for the technology to catch up to the needs of the disabled section of the society to help them also become independent and help move them forward with the rest of the society.

With the development of this application we hope to help the visually impaired community by giving them a self-sufficient application. The navigation part of the system would be clear enough to help them give a route based on their preferences and the obstacle detection can help me guide in situations when they forget their guiding devices.

Not only can we help the society become a more technologically advanced one, we can also teach the future generations to accept and respect any and all parts of the society. The only way to advance is to ensure that we can help anyone and everyone to the best of our capabilities. I do think we can still do a lot and come up with multiple apps and devices that can help the disabled people in other activities besides navigation, but I feel the society is now recognizing their needs much better now and helping them.

REFERENCES

1. Abdelsalam (Sumi) Helal, Steven Edwin Moore, Balaji Ramachandran “Drishti: An Integrated Navigation System for Visually Impaired and Disabled” in IEEE,2001
2. Dhruv Jain, Akhil Jain, Rohan Paul, Ahila Komarika, M. Balakrishnan “A path-guided audio based indoor navigation system for persons with visual impairment” in ACM, 2013
3. Ondřej Poláček, Thomas Grill, Manfred Tscheligi “Towards a Navigation System for Blind People: A Wizard of Oz Study” in ACM 2013
4. Raymond Borges Hink1, Alcides Alvear Suarez “Basic Human Computer Interface for the Blind” in LACCEI 2010
5. Kasper Hornbæk, Benjamin B. Bederson, Catherine Plaisant “Navigation Patterns and Usability of Overview+Detail and Zoomable User Interfaces for Maps” in ACM, 2002
6. Richard T. Guy, Khai N. Truong “CrossingGuard: Exploring Information Content in Navigation Aids for Visually Impaired Pedestrians” in CHI 2012
7. Anke Brock, Philippe Truillet, Bernard Oriola, Christophe Jouffrais “Usage of Multimodal Maps for Blind People: Why and How” in ACM 2010
8. Shaun K. Kane, Meredith Ringel Morris, Jacob O. Wobbrock “Touchplates: Low-Cost Tactile Overlays for Visually Impaired Touch Screen Users” in ACM 2013
9. R Development Core Team, “R: A Language and Environment for Statistical Computing”, R Foundation for Statistical Computing, Vienna, Austria, 2008, ISBN 3-900051-07-0. [Online]. Available: http://www.R-project.org
10. R. J. Freund and R. C. Littell, “SAS for linear models: a guide to the ANOVA and GLM procedures”. Sas Institute, 1981, vol. 1.
11. D. W. Hosmer Jr and S. Lemeshow,” Applied logistic regression”. John Wiley & Sons, 2004.
12. Lards Vogel “Android Camera API – Tutorial” [online] vogella
13. Michaud “Mobile App Design Project Pedometer Using Accelerometer Sensor” [online] in nebomusic
14. Android developer [online] www.developer.android.com
15. Rakesh Cusat “Android Voice Recognition Tutorial” in javacodegeeks, 2012

APPENDIX A: Survey questions

Gender

Male ☐ Female ☐

Age range

18-25 ☐ 25-35 ☐ 35-50 ☐ 50-64 ☐

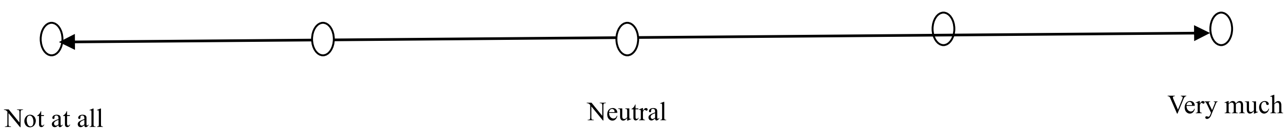
What are your occupation / major?

How often do you have to travel by yourself? How do you navigate?

What are some problems you face normally?

Is there any recent navigation problem you have faced?

How often do you use you mobile device while going from one place to another



Where do you generally keep you device, if you use it for navigation? (In hand or otherwise)

APPENDIX A (contd.)

Is there any app you use for navigation? If yes, what are your views on them? If no, why not?

How do you detect and avoid obstacles generally? What are some problems you face?

* These questions are open-ended and we might add some more related questions to them.

When and how did they lose their eyesight? (Birth problem or accident)

Is the visual impairment partial or complete?

How do they get a general understanding of the route using these apps?

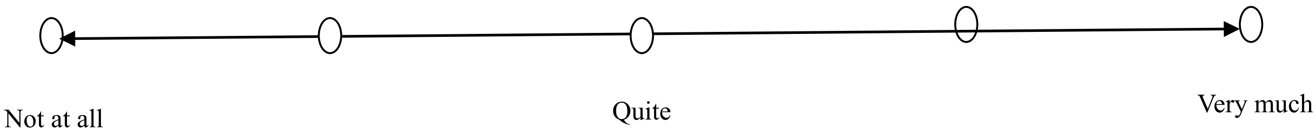
What do they do if the directions are not perfect?

How did they navigate before these smart phones?

APPENDIX B: Interview questions

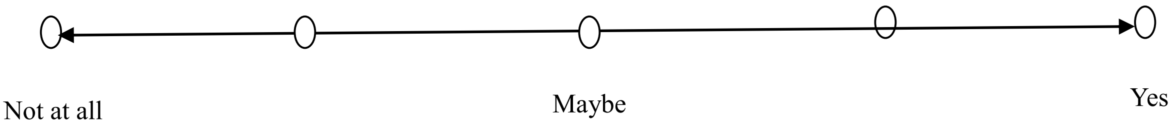
What are some of the main problem you faced while using this app?

How comfortable were you with the speech to text and text to speech system?



What are some of the features such a navigation app must have?

Would you recommend this app to your friends?



* These are the starter questions for an open-ended interview. We will proceed with points the subjects bring up from these questions.

APPENDIX C: Anova for User study 3 (Comparison between Navigator and Google Map interface): mean tables

1. Mean for Gender:

	F	M
	4	2.83
Rep	10	12

Rep means Replication. A two way ANOVA is usually done with more than one observation for each combination of the nominal variables)

2. Mean for Blindness level

	Complete	Partial
	4.59	2.91
Rep	6	16

3. Mean for interfaces

	Navigator	Google Map
	2.2	4.5
Rep	12	12

APPENDIX C (cont.)

4. Mean for Gender and Blindness level

Gender	Blindness level	
	Complete	Partial
F	5.5	3
Rep	4	6
M	3.5	2.7
Rep	2	10

5. Mean for Gender and interfaces

Gender	Interfaces	
	Navigator	Google Map
F	2.6	5.4
Rep	5	5
M	1.8	3.8
Rep	6	6

6. Mean for Blindness level and Button size

Blindness level	Interfaces	
	Navigator	Navigator
Complete	3.2	6
Rep	3	3
Partial	1.8	4
Rep	8	8

APPENDIX C (cont.)

7. Mean for Gender, Blindness level and Interface- Navigator

Gender	Blindness level	
	Complete	Partial
F	4	1.7
Rep	2	3.0
M	2.0	1.8
Rep	1	5

8. Gender, Blindness level and interface- Google map

Gender	Blindness level	
	Complete	Partial
F	7	4.3
Rep	2	3
M	5	3.6
Rep	1	5

APPENDIX D: Anova for User study 4 (Comparison between Navigator and Google Map interface): mean tables

1. Number of helping events

Mean for sets

Set	
1	2
3.2	4.7

Mean for Interface

Google Map	Navigator
1.4	6.5

Mean for set and interface both

Set: Interface		
Interface		
Set	Google Map	Navigator
1	1.3	5.2
2	1.5	7.8

APPENDIX D (contd.)

2. Number of incorrect button clicks

Mean for sets

Set	
1	2
1.17	1.42

Mean for Interface

Interface	
Google Map	Navigator
0.83	1.75

Mean for set and Interface both

Set: Interface		
Interface		
Set	Google Map	Navigator
1	0.50	1.83
2	1.17	1.67

APPENDIX D (contd.)

3. Number of incorrect turns taken

Mean for sets

Set	
1	2
2.67	2.33

Mean for Interface

Interface	
Google Map	Navigator
1.92	3.08

Mean for set and Interface both

Set: Interface		
Interface		
Set	Google Map	Navigator
1	1.8	5.2
2	2.0	2.7